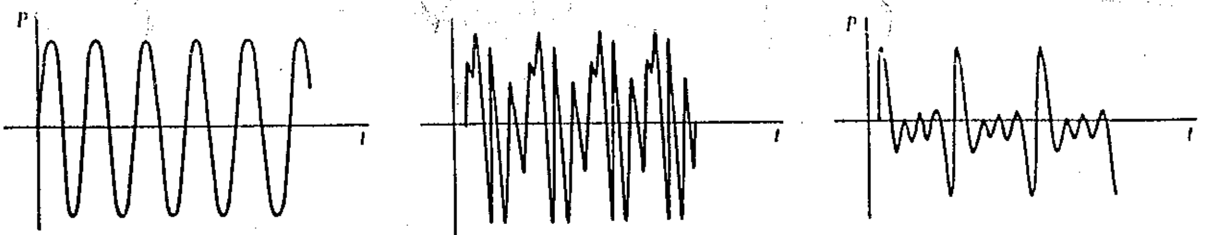
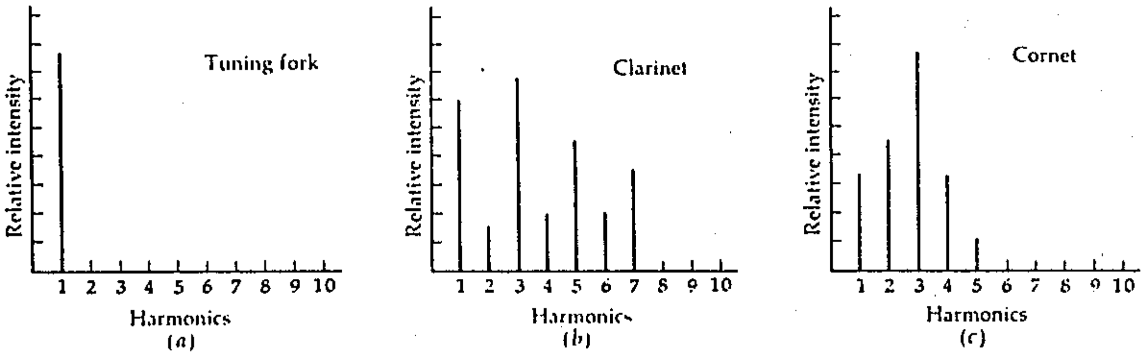


Tuning fork
(a)

Clarinet
(b)

Cornet
(c)



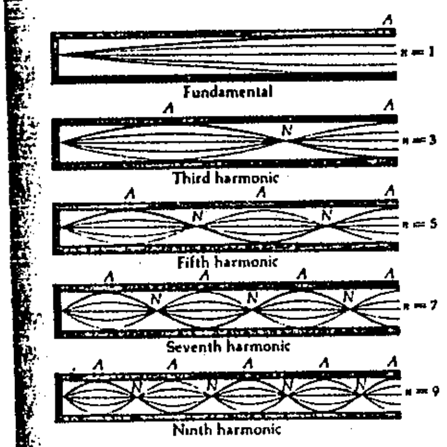


Figure 17-20
Standing-wave patterns in a pipe that is open at one end and closed at the other. These patterns are for the displacement, which has a node at the closed end and an antinode at the open end. As is the case for a string fixed at one end, only the odd harmonics are present.

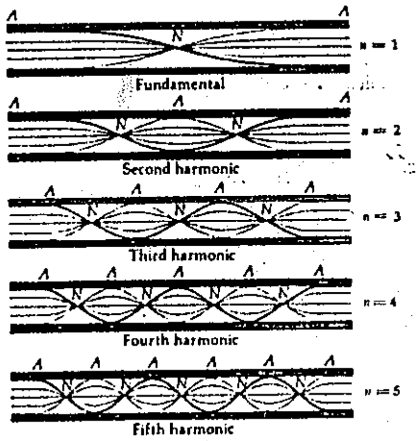
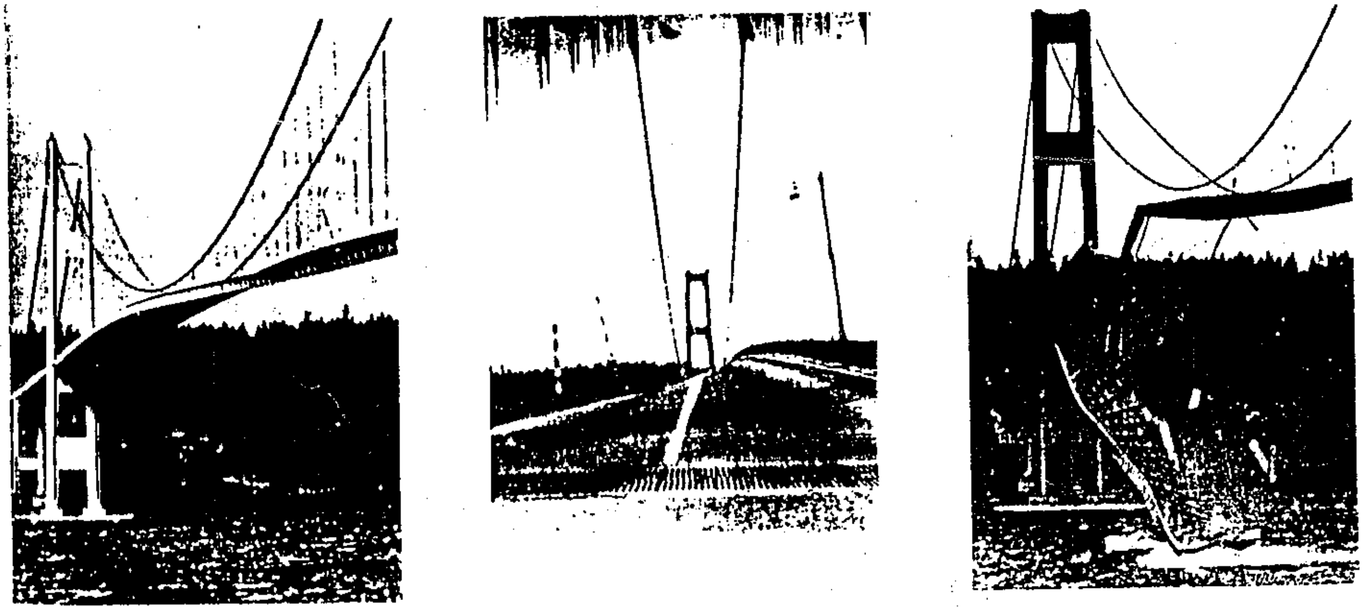
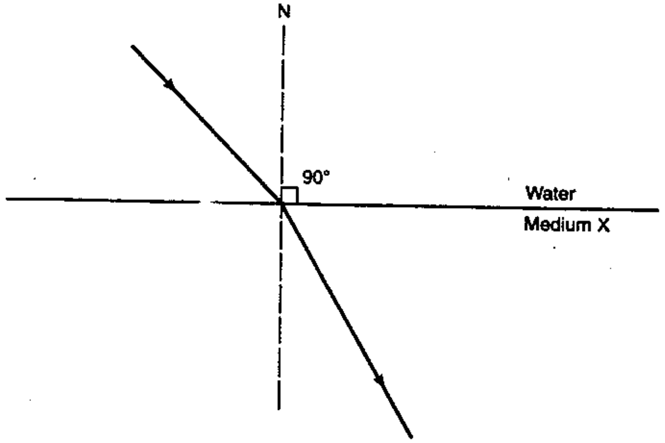


Figure 17-21
Standing-wave patterns in a pipe that is open at both ends. The displacement has an antinode at each end. As is the case for a string fixed at both ends, all harmonics are present.



Gusting winds excited standing waves in the Tacoma Narrows suspension bridge, leading to its collapse on November 7, 1940, only 4 months after it had been opened to traffic.

4. Labeling as necessary to ensure understanding, produce sketches of the following wave phenomena.
   (a) reflection
   (b) refraction
   (c) double-slit diffraction
   (d) Doppler effect
   Note: Use standard notation of f for frequency, λ for wavelength, and v for wave speed.
5. A ray of light is incident on the surface of a block of flint glass at an angle of 40. degrees. Part of the light is reflected and part is refracted. Find the angle between the reflected and refracted rays.
6. A light ray ($\lambda = 5.9 \times 10^{-7}$ meter), incident upon an interface of water and an unknown transmitting substance, X, is refracted as shown in the diagram below. Find the speed of light in medium X.



Unit 4

Pages 117–119

1.	1
2.	2
3.	4
4.	1
5.	1
6.	3
7.	2
8.	4
9.	2
10.	3
11.	1
12.	1
13.	2
14.	4
15.	2
16.	1
17.	1
18.	1
19.	3
20.	4
21.	1
22.	2
23.	2
24.	3
25.	2
26.	1
27.	1
28.	1
29.	1
30.	2
31.	2-
32.	1
33.	2

Pages 123–124

1.	4
2.	1
	3
4	4
5.	3
6.	1
7.	3
8.	1
9.	2
10.	3

Pages 137–147

1.	1
2.	2
3.	2
4.	2
5.	2
6.	4
7.	3
8.	3
9.	1
10.	4
11.	4
12.	3
13.	2
14.	3
15.	4
16.	4
17.	2
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26.	1
27.	3
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30.	2
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32.	1
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36.	4
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38.	1

39.	3
40.	1
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43.	3
44.	1
45.	2
46.	2
47.	2
48.	1
49.	3
50.	1
51.	3
52.	2
53.	2
54.	1
55.	2
56.	3
57.	1
58.	1
59.	2
60.	4
61.	3
62.	2
63.	1
64.	1
65.	2
66.	3
67.	2
68.	4
69.	2
70.	1
71.	1
72.	2
73.	3
74.	1
75.	3
76.	1
77.	4
78.	4
79.	4
80.	4
81.	3
82.	1
83.	3
84.	4
85.	1
86.	3
87.	1
88.	4
89.	3
90.	2
91.	3
92.	3
93.	1
94.	4
95.	2
96.	2
97.	1
98.	1
99.	2
100.	1
101.	2
102.	4
103.	3
104.	4
105.	1
106.	2
107.	2
108.	4
109.	3
110.	1
111.	1

Note that the subscript 1 refers to the incident medium and the subscript 2 refers to the refractive medium.

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

where $n_1 = 1.33$ (water)
$n_2 = 1.00$ (air)
$\theta_1 = 30.$ degrees

$$\sin \theta_2 = \frac{(1.33)(\sin 30^\circ)}{1.00}$$

$$\sin \theta_2 = \frac{(1.33)(0.500)}{1.00}$$

$$\sin \theta_2 = 0.665$$

$$\theta_2 = 42^\circ$$

(c) The angle of refraction is in air and is measured from the normal, using a protractor. The angle of refraction must be greater than 30 degrees because air is less dense than water, causing the light ray to travel faster in the second medium.

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Pages 277–279

1.	1
2.	2
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4.	3
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6.	2
7.	2
8.	1
9.	1
10.	3
11.	3
12.	1
13.	2
14.	1
17.	4
18.	2
19.	4
20.	3
21.	1
22.	3
23.	2
24.	2
25.	1
26.	4
27.	2
28.	2
29.	3
30.	1
31.	2
32.	4

15.	2
16.	1
17.	4
18.	1
19.	3
20.	3
21.	2
22.	3
23.	1
24.	2
25.	3
26.	2
27.	2
28.	2
29.	4

Pages 290–292

1.	3
2.	2
3.	4
4.	2
5.	4
6.	3
7.	4
8.	4
9.	3
10.	2
11.	1
12.	2
13.	4
14.	2
15.	2
16.	2

Table 9-1. The relationship be
concave mirror.

Figure	OBJECT Position
9-9a	Beyond C
9-9b	At C
9-9c	At F
9-9d	Between F and mirror

*Note that the size of the imag

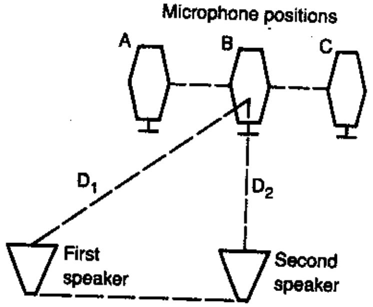
Table 9-2. The relationship
convex lens

Figure	OBJECT Position
9-18	Beyond 2F
9-19a	At 2F
9-19b	Between F and 2F
9-19c	At F
9-19d	Between F and lens

*Note that the size of the in

102–106. Base your answers to Questions 102 through 106 on the following information.

Two speakers are arranged as shown so that initially they will emit tones that are in phase, equal in volume, and equal in frequency. A microphone is placed at position *A*, which is equidistant from both speakers, and then is moved along a line parallel to the line joining the speakers until it reaches a point (position *B*) at which it picks up no sound. The microphone is then moved to position *C*, where it again picks up sound.



102. Which phenomenon caused the sound to be louder at position *C* than at position *B*? (1) reflection (2) dispersion (3) polarization (4) interference

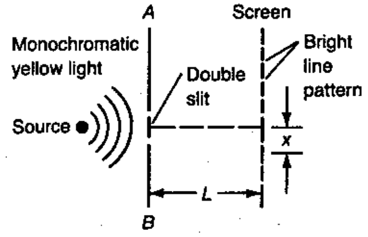
103. Distance D_2 is shorter than distance D_1 by an amount equal to (1) the wavelength of the emitted sound (2) twice the wavelength of the emitted sound (3) one-half the wavelength of the emitted sound (4) the distance between the two speakers

104. If the sound waves emitted by D_1 and D_2 have a frequency of 660 hertz and a speed of 330 meters/second, their wavelength is (1) 1.0 m (2) 2.0 m (3) 0.25 m (4) 0.50 m

105. As the first speaker is adjusted so that the sound that it emits is 180° out of phase with the sound emitted by the second speaker, the loudness of the sound received at *A* is (1) less (2) greater (3) the same

106. If speaker D_1 were removed and speaker D_2 were accelerated toward microphone *B*, the frequency of the waves detected at *B* would (1) decrease (2) increase (3) remain the same

107–111. Base your answers to Questions 107 through 111 on the diagram at right, which shows monochromatic yellow light ($\lambda = 5.9 \times 10^{-7}$ meter) directed upon two narrow slits 1.0×10^{-3} meter apart.



107. The first bright line is 5.9×10^{-3} meter from the central axis of the pattern. The distance (*L*) between the screen and *AB* is (1) 1 m (2) 10 m (3) 100 m (4) 1,000 m

108. If the screen is placed 1.0 meter from *AB*, the separation of the central maximum and the first-order bright line (*x*) is (1) 5.9×10^{-6} m (2) 2.0×10^{-5} m (3) 2.0×10^{-3} m (4) 5.9×10^{-4} m

109. This double-slit pattern is a result of (1) polarization (2) refraction (3) diffraction (4) dispersion

110. If the separation between the slits is increased, the distance between the bright lines on the screen will (1) decrease (2) increase (3) remain the same

111. If the wavelength of the light incident on the slits is decreased, the separation of the bright lines on the screen will (1) decrease (2) increase (3) remain the same

Sample Problem

Figure A depicts a ray of light ($\lambda = 5.9 \times 10^{-7}$ meter) about to emerge in air from water.

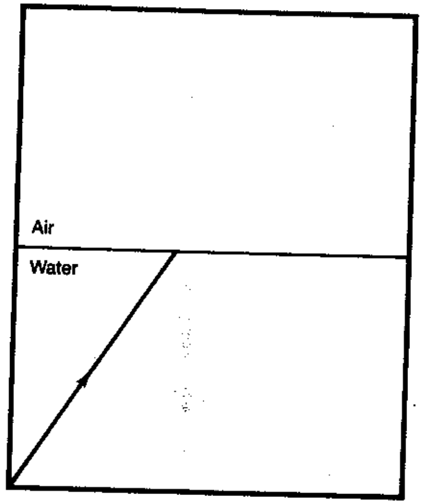


Figure A

(a) On the diagram indicate the angle of incidence by θ_i and label its measure to the nearest degree.

(b) Calculate the corresponding angle of refraction to the nearest degree. Show all work.

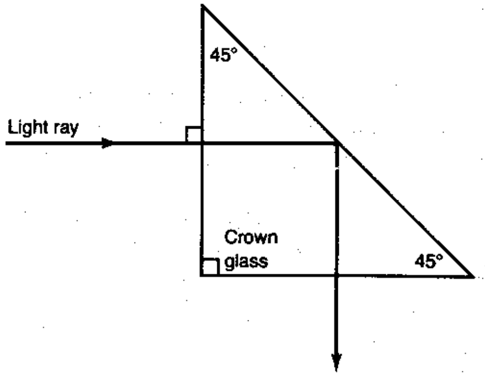
(c) On the diagram, draw the refracted light ray, label the angle of refraction $\theta_{r'}$, and indicate its measure to the nearest degree.

(d) At a boundary between two media, *some* of the incident light is always reflected. On the diagram, draw the reflected ray, label the angle of reflection θ_r, and indicate its measure to the nearest degree.

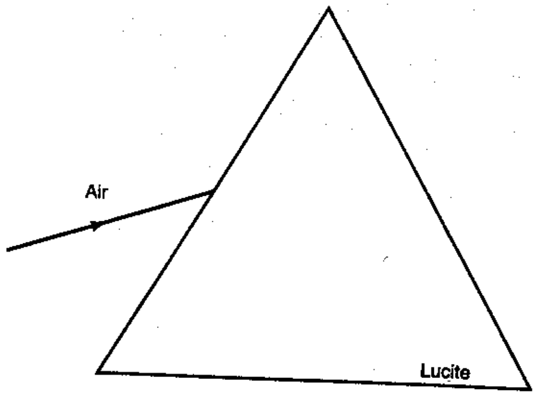
(e) If the angle of incidence is gradually changed from its present value to 55°, what changes if any would occur in the reflected and refracted rays?

Practice Problems

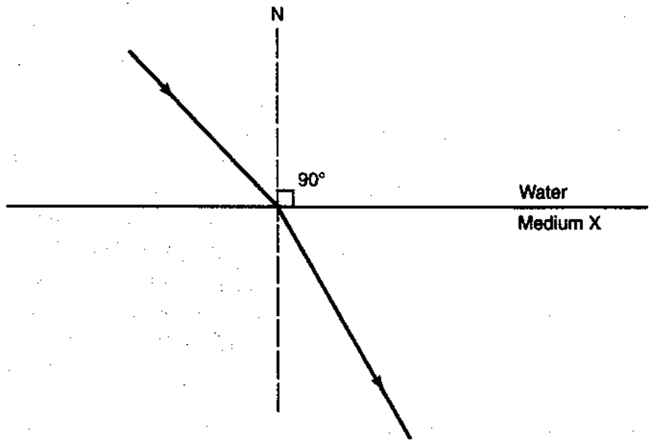
1. Explain each of the following, using physical principles.
   (a) After a picture is covered with a clear glass plate, the picture cannot be seen as distinctly.
   (b) When a person peers down into a swimming pool filled with water, the bottom appears closer to the person than it actually is.
   (c) As wind blows across the top of a chimney flue when the damper is open, the chimney "sings."
   (d) When a rapidly moving fire engine is coming toward you, the pitch of its siren sounds higher than it does when the fire engine is at rest.
2. Using your knowledge of physics, discuss the path that the light ray travels in the diagram. Be specific. Use the terms *angle of incidence, angle of reflection, angle of refraction, normal,* and *critical angle* in your answer.



3. A ray of monochromatic light ($\lambda = 5.9 \times 10^{-7}$ meter) is incident upon the triangular lucite plate as shown in the diagram. Draw the ray as it passes into and emerges from the plate. Verify your answer with calculations.



4. Labeling as necessary to ensure understanding, produce sketches of the following wave phenomena.
   (a) reflection
   (b) refraction
   (c) double-slit diffraction
   (d) Doppler effect
   Note: Use standard notation of f for frequency, λ for wavelength, and v for wave speed.
5. A ray of light is incident on the surface of a block of flint glass at an angle of 40. degrees. Part of the light is reflected and part is refracted. Find the angle between the reflected and refracted rays.
6. A light ray ($\lambda = 5.9 \times 10^{-7}$ meter), incident upon an interface of water and an unknown transmitting substance, X, is refracted as shown in the diagram below. Find the speed of light in medium X.



Unit 4

Pages 117–119

1.	1
2.	2
3.	4
4.	1
5.	1
6.	3
7.	2
8.	4
9.	2
10.	3
11.	1
12.	1
13.	2
14.	4
15.	2
16.	1
17.	1
18.	1
19.	3
20.	4
21.	1
22.	2
23.	2
24.	3
25.	2
26.	1
27.	1
28.	1
29.	1
30.	2
31.	2
32.	1
33.	2

Pages 123–124

1.	4
2.	1
	3
4	4
5.	3
6.	1
7.	3
8.	1
9.	2
10.	3

Pages 137–147

1.	1
2.	2
3.	2
4.	2
5.	2
6.	4
7.	3
8.	3
9.	1
10.	4
11.	4
12.	3
13.	2
14.	3
15.	4
16.	4
17.	2
18.	4
19.	4
20.	1
21.	2
22.	4
23.	1
24.	1
25.	1
26.	1
27.	3
28.	1
29.	1
30.	2
31.	2
32.	1
33.	3
34.	2
35.	1
36.	4
37.	3
38.	1
39.	3
40.	1
41.	3
42.	2
43.	3
44.	1
45.	2
46.	2
47.	2
48.	1
49.	3
50.	1
51.	3
52.	2
53.	2
54.	1
55.	2
56.	3
57.	1
58.	1
59.	2
60.	4
61.	3
62.	2
63.	1
64.	1
65.	2
66.	3
67.	2
68.	4
69.	2
70.	1
71.	1
72.	2
73.	3
74.	1
75.	3
76.	1
77.	4
78.	4
79.	4
80.	4
81.	3
82.	1
83.	3
84.	4
85.	1
86.	3
87.	1
88.	4
89.	3
90.	2
91.	3
92.	3
93.	1
94.	4
95.	2
96.	2
97.	1
98.	1
99.	2
100.	1
101.	2
102.	4
103.	3
104.	4
105.	1
106.	2
107.	2
108.	4
109.	3
110.	1
111.	1

Solution

(a) To determine the angle of incidence, a normal to the surface at the point of incidence should be drawn first. The angle of incidence is measured from the normal. See Figure B at the top of the next page.

(b) Snell's law is given by:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

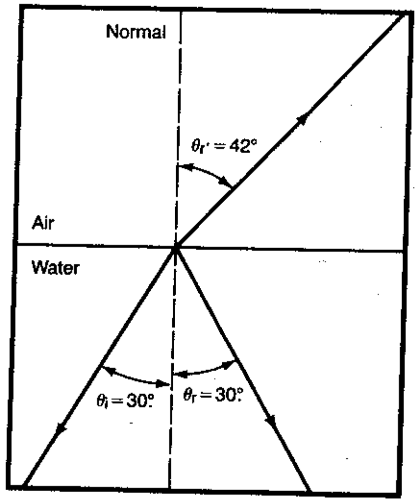


Figure B

Note that the subscript *1* refers to the incident medium and the subscript 2 refers to the refractive medium.

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2} \qquad \text{where } n_1 = 1.33 \text{ (water)}, \; n_2 = 1.00 \text{ (air)}, \; \theta_1 = 30. \text{ degrees}$$

$$\sin \theta_2 = \frac{(1.33)(\sin 30°)}{1.00}$$

$$\sin \theta_2 = \frac{(1.33)(0.500)}{1.00}$$

$$\sin \theta_2 = 0.665$$

$$\theta_2 = 42°$$

(c) The angle of refraction is in air and is measured from the normal, using a protractor. The angle of refraction must be greater than 30 degrees because air is less dense than water, causing the light ray to travel faster in the second medium.

(d) At the interface between the two media, there is a partial reflection of the original ray. According to the law of reflection, the angle of incidence must equal the angle of reflection. Thus, the angle of reflection is 30. degrees, and is measured from the normal.

(e) Increasing the angle of incidence would cause an equal increase in the angle of reflection. However, the angle of refraction would increase only until it reached its maximum value of 90.°, when the angle of incidence is the critical angle for water. As the angle of incidence is made to exceed the critical angle, there would be total internal reflection.

Various skills were needed to solve the above problem. In addition to measuring, applying mathematics, and communicating information, you had to predict what would happen if one of the variables in the problem was changed.

Pages 148–151 Problem Solving

1. (a) When light meets a boundary between two media, not all of the light in the first medium is transmitted through the second medium. Part of the light coming from the picture is reflected by the glass and part is absorbed by it. The amount of light coming from the picture is therefore decreased by the presence of the glass. As a result, the viewer sees the picture less distinctly.
   (b) The brain perceives light as traveling in a straight line. However, light originating in water that meets a water-air boundary at an oblique angle is refracted away from the normal to the boundary. Thus, the light changes direction as it passes from the water in the pool to the air, a change that the brain cannot perceive. As a result, the observer outside the pool perceives the bottom of the pool to be closer to the surface than it actually is.
   (c) The column of air in the chimney resonates, producing the "singing" noise. A standing wave exists in the chimney, similar to the standing waves that exist in organ pipes.
   (d) The fire engine produces a sound of constant frequency, or pitch. As the engine approaches you, the distance between successive wave fronts that reach you is decreased. (The fire engine is trying to "catch" the wave front just produced.) Since the speed of sound is constant, a decrease in wavelength produces an observed increase in frequency or pitch. This effect is called the Doppler effect.
2. The light ray strikes the crown glass at an angle of incidence of 0°—that is, the angle between the incident ray and the surface of the glass is 90.°. The light slows down as it enters the glass, but the ray is not refracted. The ray makes an angle of 45° with the next glass-air interface and consequently has an angle of incidence of 45° (90.° – 45° = 45°). Since this angle of incidence exceeds the critical angle for crown glass, the light experiences total internal reflection (at an angle of 45° to the normal). The reflected light then strikes the glass-air interface perpendicularly. Thus, the light is not refracted as it enters the air, although its speed increases.
3. The light ray is refracted when it passes into the Lucite plate and obeys Snell's Law. In the expressions below, Snell's Law is used to find the angle of refraction in Lucite. The subscript 1 refers to air and the subscript 2 refers to Lucite:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

$$\sin \theta_2 = \frac{1.00 \times \sin 49°}{1.50}$$

$$\sin \theta_2 = \frac{1.00 \times 0.7547}{1.50} = 0.503$$

$$\theta_2 = 30.°$$

In the Lucite plate, the ray has an angle of incidence of 30.°. Snell's Law can be used again to calculate the angle of refraction in air. Note that for this calculation, the ray originates in Lucite, which is denoted below by the subscript 1. Air is denoted by the subscript 2:

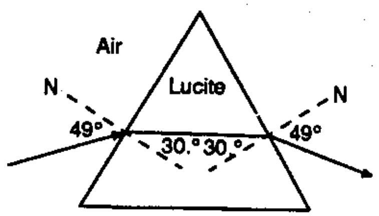
$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

$$\sin \theta_2 = \frac{1.50 \times \sin 30.°}{1.00}$$

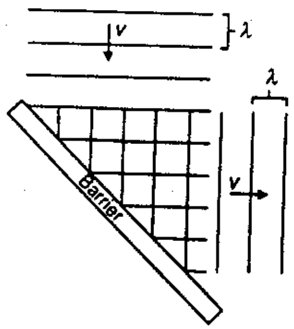
$$\sin \theta_2 = \frac{1.50 \times 0.5000}{1.00} = 0.750$$

$$\theta_2 = 49°$$

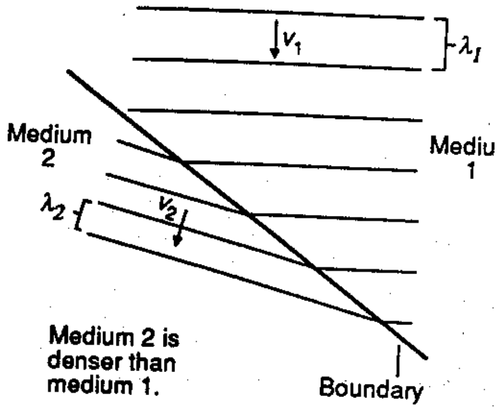
The path of the light is shown in the illustration.



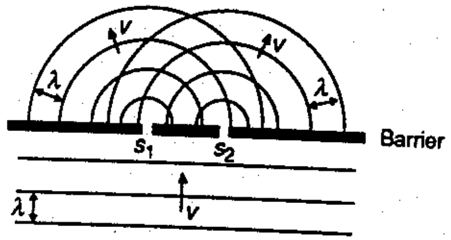
4. (a) Reflection



(b) Refraction

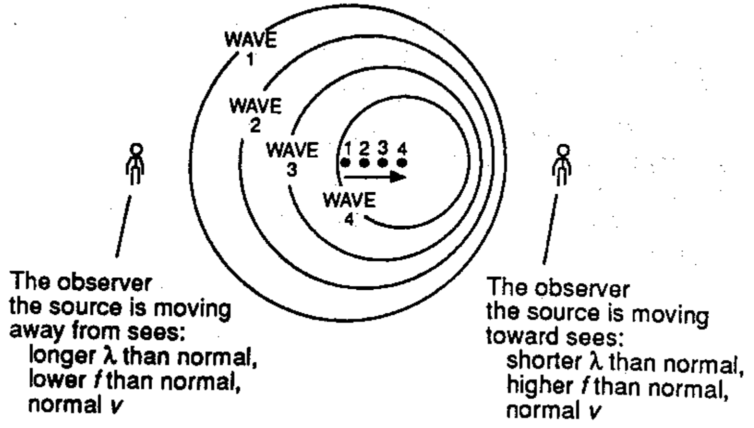


(c) Double-slit diffraction



(d) Doppler effect

The drawing shows a wave source moving to the right at a constant speed, producing successively waves 1, 2, 3, and 4



5. The angle of reflection equals the angle of incidence, 40.°. The angle of refraction can be found using Snell's Law. In applying Snell's Law below, the subscript 1 is used to denote air, and the subscript 2 is used to denote flint glass:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

$$\sin \theta_2 = \frac{1.00 \times \sin 40.°}{1.61}$$

$$\sin \theta_2 = \frac{1.00 \times 0.6428}{1.61} = 0.399$$

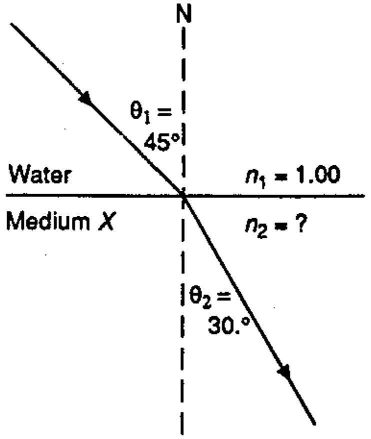
$$\theta_2 = 24°$$

Therefore, the angle between the reflected and refracted rays is equal to 180° minus the sum of the angle of reflection and angle of refraction:

180° – (angle of reflection + angle of refraction)

$180° - (40.° + 24°) = 180° - 64° = 116°$

6.



In applying Snell's Law, the subscript A represents air and the subscript X represents the unknown substance:

$$n_A \sin \theta_A = n_X \sin \theta_X$$

$$n_X = \frac{n_A \sin \theta_A}{\sin \theta_X}$$

The angles, as measured by a protractor, are $\theta_A = 45°$ and $\theta_X = 30.°$. Therefore,

$$n_X = \frac{1.00 \times \sin 45°}{\sin 30.°}$$

$$n_X = \frac{1.00 \times 0.7071}{0.5000} = 1.41$$

Since $n = \frac{c}{v}$, it follows that

$$v = \frac{c}{n} = \frac{3.0 \times 10^8 \text{ m/s}}{1.41} = 2.1 \times 10^8 \text{ m/s}$$

Thus, the speed of light in medium X is 2.1×10^8 m/s.

1. The image produced by a plane mirror is always (1) virtual and erect (2) virtual and inverted (3) real and erect (4) real and inverted

2. A student 1.8 meters tall stands 1.0 meter in front of a plane mirror. The height of the image is (1) 1.0 m (2) 1.8 m (3) 2.8 m (4) 0.20 m

3. As a student approaches a plane mirror, the size of her image (1) decreases (2) increases (3) remains the same

4. The image seen in a vertical plane mirror is always (1) inverted and reversed (2) inverted and real (3) erect and reversed (4) erect and real

5. A light ray incident perpendicular to a plane mirror will be reflected at an angle to the mirror of (1) 0° (2) 30° (3) 45° (4) 90°

6. Compared to the focal length of a spherical mirror, the radius of curvature of a spherical mirror is (1) one-half as long (2) twice as long (3) the same length (4) four times as long

7. Incident rays parallel to the principal axis of a spherical concave mirror are reflected (1) through the center of curvature (2) through the principal focus (3) perpendicular to the principal axis (4) through a point midway between the principal focus and the center of curvature

8. Light rays directed toward the center of curvature of a spherical mirror strike the mirror at an angle to the normal of (1) 0° (2) 30° (3) 60° (4) 90°

9. The measure of the angle between an incident light ray directed toward the center of curvature of a spherical mirror and its reflected ray is (1) 0° (2) 45° (3) 90° (4) 180°

10. Which of the following will cause parallel light rays to converge? (1) concave lens (2) plane mirror (3) concave mirror (4) convex mirror

11–14. Base your answers to Questions 12 through 15 on the information below.

An object is located at the center of curvature *C* of a concave mirror with principal focus *F*.

11. Compared to the size of the object, the size of the image is (1) smaller (2) larger (3) the same

12. As the object is moved farther away from the mirror, the size of its image (1) decreases (2) increases (3) remains the same

13. If the object is located beyond *C*, the image is located (1) beyond *C* (2) between *C* and *F* (3) at *F* (4) between *F* and the mirror

14. If the object is moved inside of *F*, the resulting image is (1) virtual and larger than the object (2) virtual and smaller than the object (3) real and larger than the object (4) real and smaller than the object

15. Which of the following will *always* cause parallel light rays to diverge? (1) concave mirror (2) convex mirror (3) plane mirror (4) convex lens

16. Which of the following is true of the focal length and image distance for a convex mirror? (1) Both are negative. (2) Both are positive. (3) Focal length is negative and image distance is positive. (4) Focal length is positive and image distance is negative.

17. An image formed by a convex mirror is always (1) real and larger than the object (2) real and smaller than the object (3) virtual and larger than the object (4) virtual and smaller than the object

18. Not all of the parallel light rays incident on a concave mirror converge at the principal focus. This phenomenon is called (1) spherical aberration (2) chromatic aberration (3) diffraction (4) refraction

19. Which of the following produce only virtual images? (1) convex lens and convex mirror (2) convex lens and concave mirror (3) concave lens and convex mirror (4) concave lens and concave mirror.

20–26. Base your answers to Questions 21 through 25 on the information below.

An object 0.10 meter tall is placed 0.60 meter in front of a concave mirror having a focal length of 0.40 meter.

20. The radius of curvature of the mirror is (1) 0.20 m (2) 0.40 m (3) 0.80 m (4) 1.2 m

21. The image distance is (1) 1.0 m (2) 1.2 m (3) 0.83 m (4) 0.24 m

22. The size of the image is (1) 0.10 m (2) 0.14 m (3) 0.20 m (4) 0.50 m

23. The image produced is (1) real and inverted (2) real and erect (3) virtual and inverted (4) virtual and erect

24. If the object were moved to 0.80 meter from the mirror, the size of the image would be (1) 0.050 m (2) 0.10 m (3) 0.20 m (4) 0.80 m

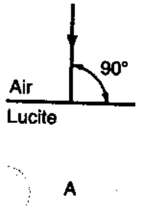
25. Compared to the size of the object at a distance of 0.80 m from the mirror, the size of the image is (1) less (2) greater (3) the same

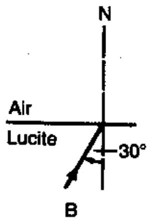
26. The object is moved to 0.20 meter from the mirror. Compared to the size of the object, the size of the image is (1) less (2) greater (3) the same

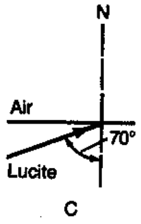
38. When a ray of light strikes a mirror perpendicular to its surface, the angle of reflection will be (1) 0° (2) 45° (3) 60° (4) 90°

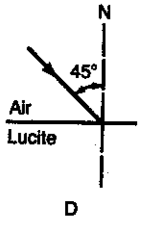
39. A light beam from the earth is reflected by an object in space. If the round trip for the beam takes 2.0 seconds, then the distance of the object from earth is (1) 6.7×10^7 m (2) 1.5×10^8 m (3) 3.0×10^8 m (4) 6.0×10^8 m

40–43. Base your answers to Questions 40 through 43 on the diagrams below, which show the paths of four rays of monochromatic light as they reach the boundary between two media. *N* is the normal to the surface.









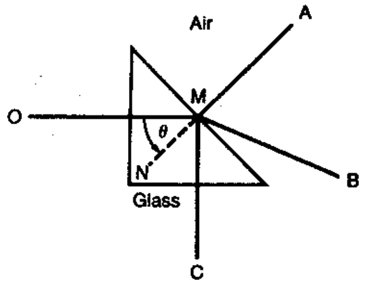
40. The direction of the ray of light will not change as the light enters the other medium in diagram (1) *A* (2) *B* (3) *C* (4) *D*

41. The ray of light will undergo total internal reflection at the boundary in diagram (1) *A* (2) *B* (3) *C* (4) *D*

42. The angle of refraction of the ray of light will be greater than the angle of incidence in diagram (1) *A* (2) *B* (3) *C* (4) *D*

43. What is the sine of the angle of refraction for the ray of light in diagram *D*? (1) 1.00 (2) 0.71 (3) 0.47 (4) 0.30

44–48. Base your answers to Questions 44 through 48 on the diagram, which shows a glass prism surrounded by air. The dashed line *MN* is a normal and is extended to *A*.



44. Which phenomenon would cause monochromatic light entering the prism along path *OM* to leave along path *MC*? (1) reflection (2) refraction (3) dispersion (4) diffraction

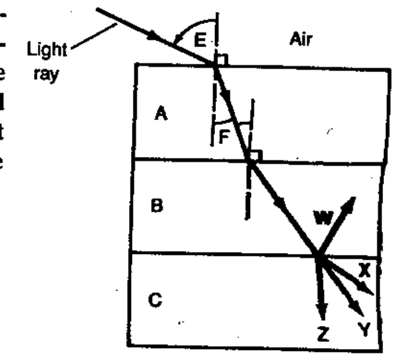
45. If the index of refraction of the prism is 1.5, then the speed of light in this prism is (1) 1.5×10^8 m/s (2) 2.0×10^8 m/s (3) 3.0×10^8 m/s (4) 4.5×10^8 m/s

. A ray of light striking the prism along path *AM* will follow path (1) *MO* (2) *MN* (3) *MB* (4) *MC*

47. Compared with the index of refraction for blue light, the index of refraction of this glass prism for red light is (1) greater (2) less (3) equal

48. If all the light entering the prism along path *OM* emerges along path *MC*, then angle *θ* is (1) greater than the critical angle (2) less than the critical angle (3) equal to the critical angle

49–53. Base your answers to Questions 49 through 53 on the diagram, which represents three transparent media arranged one on top of the other. A light ray in air is incident on the upper surface of layer *A*.



49. If layers *B* and *C* have the same index of refraction, in which direction will the light ray travel after reaching the boundary between layers *B* and *C*? (1) *W* (2) *X* (3) *Y* (4) *Z*

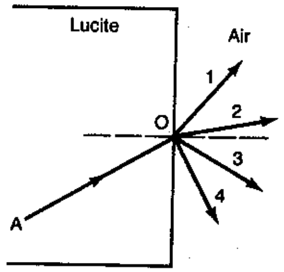
50. If layer *A* were lucite, then layer *B* could be (1) water (2) diamond (3) Canada balsam (4) flint glass

51. If angle *E* is 60° and layer *A* has an index of refraction of 1.61, the sine of angle *F* will be closest to (1) 1.00 (2) 0.866 (3) 0.538 (4) 0.400

52. If angle *E* were increased, then angle *F* would (1) decrease (2) increase (3) remain the same

53. Compared to the apparent speed of light in layer *A*, the apparent speed of light in layer *B* is (1) slower (2) faster (3) the same

54–58. Base your answers to Questions 54 through 58 on the diagram, which shows a narrow beam of monochromatic yellow light passing from lucite into air.



54. Which path will the ray *AO* follow? (1) 1 (2) 2 (3) 3 (4) 4

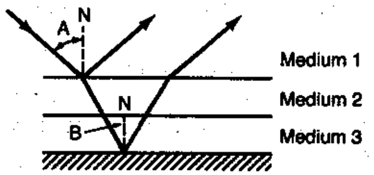
55. The speed of the light beam in the lucite is (1) 1.0×10^8 m/s (2) 2.0×10^8 m/s (3) 3.0×10^8 m/s (4) 4.5×10^8 m/s

56. As the beam passes from lucite to air, its frequency (1) decreases (2) increases (3) remains the same

57. If the monochromatic yellow beam is replaced by a monochromatic violet beam, the speed of this light in lucite would be (1) slower (2) faster (3) the same

58. If the lucite were replaced by flint glass, the critical angle would be (1) smaller (2) larger (3) the same

59–63. Base your answers to Questions 59 through 63 on the diagram, which shows a ray of monochromatic light as it travels in three transparent media.



59. What happens to the light incident upon medium *2* from medium *1*? (1) All of the light is refracted. (2) Part of the light is refracted and part is reflected. (3) Part of the light is refracted and part is dispersed. (4) Part of the light is diffracted and part is reflected.

60. If medium *2* is corn oil, then medium *3* could be (1) crown glass (2) flint glass (3) lucite (4) glycerol

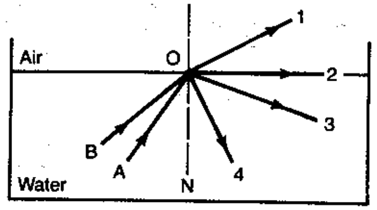
61. As the light enters medium *2*, its frequency (1) decreases (2) increases (3) remains the same

62. If angle *A* is increased, angle *B* will (1) decrease (2) increase (3) remain the same

63. If the frequency of the light incident in medium *1* is increased, its wavelength in medium *1* will (1) decrease (2) increase (3) remain the same

64–67. Base your answers to Questions 64 through 67 on the following information.

Two rays of monochromatic yellow light, *A* and *B*, originate in a tank of water as shown. Angle *BON* is the critical angle of water.



64. Ray *A* will travel along path (1) 1 (2) 2 (3) 3 (4) 4

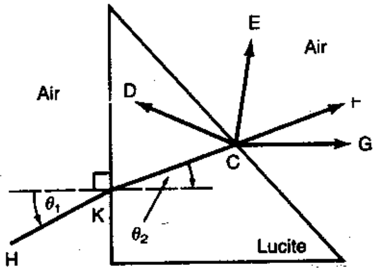
65. The sine of the critical angle for water is equal to

(1) $\frac{1.33}{1}$ (2) $\frac{1}{1.33}$ (3) $\frac{3 \times 10^8}{1.33}$ (4) $3 \times 10^8 \times 1.33$

66. As a ray of light in the tank undergoes total internal reflection, its speed will (1) decrease (2) increase (3) remain the same

67. As a ray of light traveling along path *NO* enters the air, its speed will (1) decrease (2) increase (3) remain the same

68–72. Base your answers to Questions 68 through 72 on the diagram, which represents a lucite prism. *HK* is a narrow beam of monochromatic yellow light incident upon the prism at angle *θ*.



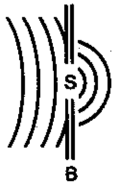
68. Which represents the path of *HK*? (1) *HKCD* (2) *HKCE* (3) *HKCF* (4) *HKCG*
69. The speed of the light beam through the lucite prism is (1) 1.0×10^8 m/s (2) 2.0×10^8 m/s (3) 3.0×10^8 m/s (4) 4.0×10^8 m/s
70. If angle θ_1 is 30°, the sine of angle θ_2 is

(1) $\frac{0.50}{1.5}$ (2) $\frac{0.87}{1.5}$ (3) $\frac{1.5}{0.50}$ (4) $\frac{1.5}{0.87}$

71. If the monochromatic yellow beam is replaced by a monochromatic blue beam, angle θ_2 (1) decreases (2) increases (3) remains the same
72. As angle θ_1 increases from 20° to 30°, angle θ_2 (1) decreases (2) increases (3) remains the same

73. The spreading of a wave front into the region behind an obstruction is known as (1) reflection (2) refraction (3) diffraction (4) dispersion

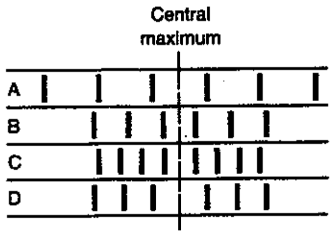
74. Which phenomenon is evidence of the transverse nature of light? (1) polarization (2) reflection (3) diffraction (4) interference
75. As a periodic wave passes into a new medium where the wave speed is greater, the (1) frequency increases (2) frequency decreases (3) wavelength increases (4) wavelength decreases
76. The wave phenomenon that could not be demonstrated with a single wave pulse is (1) a standing wave (2) diffraction (3) reflection (4) refraction
77. Refraction of a monochromatic light wave is caused by a change in the wave's (1) amplitude (2) frequency (3) wavelength (4) speed
78. Which phenomenon is associated only with transverse waves? (1) interference (2) dispersion (3) refraction (4) polarization
79. Sources that produce waves with a constant phase relation are said to be (1) polarized (2) diffused (3) refracted (4) coherent
80. The diagram shows light waves passing through slit *S* in barrier *B*. This is an example of
(1) reflection
(2) refraction
(3) polarization
(4) diffraction



81. The speed at which light passes through a material medium depends on the (1) frequency of the light only (2) nature of the medium only (3) frequency of the light and the nature of the medium (4) angle of incidence to the medium

82. Which waves require a material medium for transmission? (1) sound waves (2) radio waves (3) x rays (4) visible light
83. The change in direction that occurs when a wave passes obliquely from one medium into another is called (1) diffraction (2) interference (3) refraction (4) superposition

84–87. Base your answers to Questions 84 through 87 on diagrams *A* through *D*, which represent four interference patterns. The dark bars indicate areas of *minimum* light intensity.

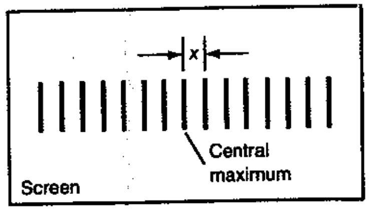


84. Which phenomenon was primarily responsible for producing all four interference patterns? (1) polarization (2) dispersion (3) refraction (4) diffraction
85. If the distance from the slits to the screen upon which pattern *B* is displayed is increased, then the most likely pattern to appear would be (1) *A* (2) *B* (3) *C* (4) *D*

86. In pattern *C*, the distance between the central maximum and the first bright line is 2.0×10^{-2} meter. The separation of the double slit is 1.0×10^{-4} meter and the distance from the slits to the screen is 4.0 meters. The wavelength of the source is (1) 2.2×10^{-3} m (2) 8.0×10^2 m (3) 5.0×10^{-7} m (4) 1.5×10^{-6} m
87. If pattern *B* is produced by using monochromatic green light and the source is changed to monochromatic red light, then the pattern produced would become like pattern (1) *A* (2) *B* (3) *C* (4) *D*

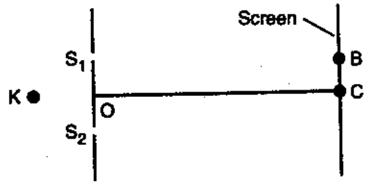
88–91. Base your answers to questions 88 through 91 on the following information.

A source of monochromatic light with a wavelength of 6.0×10^{-7} meter is incident upon two slits that are 2.0×10^{-5} meter apart and 2.0 meters from a screen. The dark bars on the screen represent the ***bright*** areas in the interference pattern produced on the screen.



88. The color of the incident light is (1) green (2) yellow (3) red (4) orange
89. Distance *x* is equal to (1) 1.7×10^{-2} m (2) 3.0×10^{-2} m (3) 6.0×10^{-2} m (4) 1.2×10^{-1} m
90. If the distance between the slits and the screen is increased, distance *x* will (1) decrease (2) increase (3) remain the same
91. If the light source is made brighter, distance *x* will (1) decrease (2) increase (3) remain the same

92–96. Base your answers to Questions 92 through 96 on the diagram, which represents light from a monochromatic source, *K*, passing through narrow slits S_1 and S_2. A central bright band is observed at *C* and a first-order bright band is observed at *B*. The two slits are 1.1×10^{-4} meter apart, distance *OC* is 2.0 meters and distance *CB* is 1.0×10^{-2} meter.

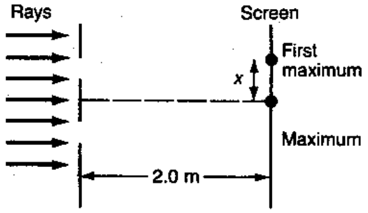


92. Light arrives at point *B* from slit S_2 because of (1) dispersion (2) refraction (3) diffraction (4) polarization
93. Which phenomenon of light causes the bright band at *B*? (1) interference (2) refraction (3) dispersion (4) polarization
94. What is the color of the light coming from source *K*? (1) orange (2) yellow (3) blue (4) green
95. If red light had been used, the distance *BC* would have been (1) shorter (2) longer (3) the same

96. If the two slits are moved closer together, the distance *BC* will (1) decrease (2) increase (3) remain the same

97–101. Base your answers to Questions 97 through 101 on the following information.

Two parallel slits 2.0×10^{-6} meter apart are illuminated by parallel rays of monochromatic light of wavelength 6.0×10^{-7} meter, as shown. The interference pattern is formed on a screen 2.0 meters from the slits.



97. The distance *X* is (1) 6.0×10^{-1} m (2) 6.0×10^{-7} m (3) 3.0×10^{-1} m (4) 3.3 m
98. The difference between the distances from each of the slits to the first maximum is (1) λ (2) 2λ (3) λ/2 (4) 0
99. If the wavelength of the light passing through the slits is doubled, the distance from the central maximum to the first maximum (1) decreases (2) increases (3) remains the same
100. If the screen is moved closer to the slits, the distance between the central maximum and the first maximum (1) decreases (2) increases (3) remains the same
101. If the distance between the slits decreases, the distance between the central maximum and the first maximum (1) decreases (2) increases (3) remains the same

7. Two waves will produce a standing wave in a medium if they have (1) the same frequency, different amplitudes, and the same direction of travel (2) the same frequency, the same amplitude, and the same direction of travel (3) the same frequency, the same amplitude, and opposite directions of travel (4) different frequencies, the same amplitude, and the same direction of travel

8. When two waves pass each other in a medium, maximum constructive interference will occur in places where the phase difference between the two waves is (1) 0° (2) 45° (3) 90° (4) 180°

9. A vibrator is used to produce standing waves in a stretched string. As the frequency of the vibrator increases, the number of nodes in the string (1) decreases (2) increases (3) remains the same

10. As a periodic wave passes into a different medium in which the speed of the wave decreases, the frequency of the wave (1) decreases (2) increases (3) remains the same

1. If the speed of light in a vacuum is *c*, the speed of light in a medium with an index of refraction of 2 is (1) *c*/2 (2) 2*c* (3) *c*/4 (4) 4*c*

2. A ray of light traveling through water strikes the water-air boundary with an angle of incidence equal to the critical angle. The angle of refraction is (1) 180.° (2) 90.° (3) 45° (4) 30.°

3. The frequency of infrared waves is generally greater than that of (1) visible light rays (2) radio waves (3) ultraviolet waves (4) x rays

4. If a ray of monochromatic yellow light ($\lambda = 5.9 \times 10^{-7}$ m) traveling through the air is incident to a refractive medium at an angle of 30°, the material that would produce the largest angle of refraction is (1) alcohol (2) water (3) glycerol (4) lucite

5. If the speed of light in a medium is 1.5×10^8 meters per second, the index of refraction of the medium is (1) 0.67 (2) 2.0 (3) 3.0 (4) 2.5

6. The critical angle for light passing from a special glass into air is 41°. When the angle of incidence equals the critical angle, the angle of refraction will be (1) between 0° and 41° (2) 41° (3) between 41° and 90.° (4) 90.°

7. A beam of light traveling in air is incident upon a glass block. If the angle of refraction is 30.°, the angle of incidence is (1) 0° (2) between 0° and 30.° (3) between 30.° and 90.° (4) 90.°

8. Which type of electromagnetic wave has the highest frequency? (1) radio (2) infrared (3) x ray (4) visible

9. The separation of white light into component colors as it passes through a triangular glass prism is (1) dispersion (2) diffraction (3) diffusion (4) interference

10. Patterns that are produced on a screen by passing coherent light through a double slit can be explained in terms of which of the following phenomena of light? (1) refraction and dispersion (2) diffraction and dispersion (3) diffraction and refraction (4) diffraction and interference

11. When a beam of white light passes obliquely from air into glass, which component experiences the greatest change in direction? (1) red (2) yellow (3) green (4) blue

12. To form a diffraction (interference) pattern from two light sources, the sources must (1) have different frequencies (2) have different intensities (3) be coherent (4) be incoherent

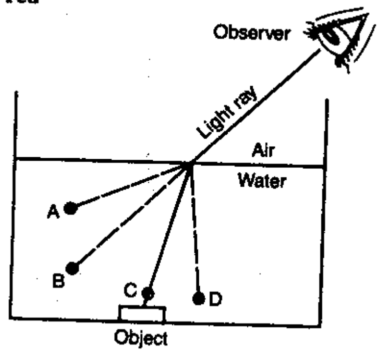
13. The speed of light in a transparent medium is three-fourths that in a vacuum. The index of refraction of the medium is
(1) $\frac{3}{4}$ (2) $\frac{4}{3}$ (3) $\frac{\sqrt{3}}{2}$ (4) $\frac{\sqrt{2}}{3}$

14. Maximum destructive interference occurs when the phase difference between two waves traveling in the same medium is (1) 0° (2) 90° (3) 180° (4) 270°

15. The critical angle is that angle of incidence that produces an angle of refraction of (1) 0° (2) 45° (3) 60.° (4) 90.°

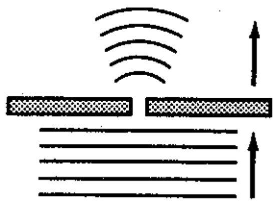
16. What is the color of light with a wavelength of 6.9×10^{-7} meter? (1) blue (2) green (3) yellow (4) red

17. An object resting on the bottom of a tank of water as shown in the diagram is being observed. To the observer, the object will appear to be located at point
(1) *A* (3) *C*
(2) *B* (4) *D*



18. A light ray traveling through glass strikes a glass-air surface. The angle of incidence equals the critical angle of 42°. The angle that the refracted ray makes with the normal is (1) 0° (2) 42° (3) 48° (4) 90.°

19. The diagram at the right represents straight wave fronts passing through an opening in a barrier. Which wave phenomenon is exhibited? (1) refraction (2) polarization (3) dispersion (4) diffraction



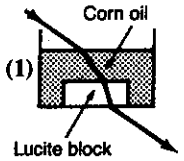
20. Light of a single frequency cannot be (1) dispersed (2) reflected (3) refracted (4) diffracted

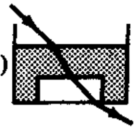
21. Which type of wave can be polarized? (1) sound (2) light (3) compression (4) any type

22. A wave passes obliquely from a medium having an index of refraction of 1.3 to a different medium. The wave will bend toward the normal in the second medium if its index of refraction is (1) 1.0 (2) 1.2 (3) 1.3 (4) 1.4

23. Double-slit interference experiments with light were important in establishing the (1) wave theory (2) corpuscular theory (3) quantum theory (4) electromagnetic theory

24. Which diagram shows the path that a monochromatic ray of light will travel as it passes through air, corn oil, lucite, and back into air?

(1)


(2)


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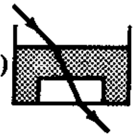

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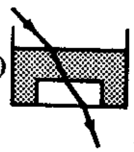


25. As the index of refraction of an alcohol and water mixture increases, the critical angle for the mixture (1) decreases (2) increases (3) remains the same

26. When the index of refraction of a medium increases, the speed of light through the medium (1) decreases (2) increases (3) remains the same

27. A light ray traveling through glass strikes a glass-air surface. As the angle of incidence increases, the critical angle for the glass (1) decreases (2) increases (3) remains the same

28. As the absolute index of refraction of a substance increases, its critical angle (1) decreases (2) increases (3) remains the same

29. As a beam of monochromatic light travels from one medium to another of higher refractive index, the wavelength of the light (1) decreases (2) increases (3) remains the same

30. The speed of light changes when light is (1) polarized (2) refracted (3) reflected (4) diffracted

31. A person standing on a straight railroad track hears the whistle of an approaching train. As the train approaches with a constant velocity, the frequency that the person observes for the whistle, compared to the frequency observed by a person riding on the train, is (1) lower (2) higher (3) the same

32. The speed of monochromatic blue light in glass, compared to the speed of monochromatic red light in the same glass, is (1) less (2) greater (3) the same

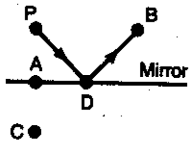
33. A ray of monochromatic light passes from air into water. As the angle of incidence of the light ray increases, the index of refraction of the water (1) decreases (2) increases (3) remains the same

34. As the angle of incidence of a light wave entering glass from air increases, the angle of refraction (1) decreases (2) increases (3) remains the same

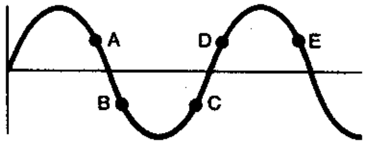
35. A ray of light is reflected from a plane mirror. If the angle between the incident and reflected rays is 40°, the angle of incidence is (1) 20° (2) 40° (3) 50° (4) 70°

36. Which wave phenomenon best supports the fact that light travels as a transverse wave? (1) reflection (2) refraction (3) dispersion (4) polarization

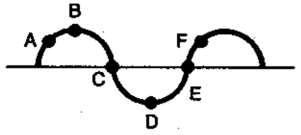
37. To an observer at *B*, light rays emitted from point *P* will appear to originate at point (1) *A* (2) *B* (3) *C* (4) *P*



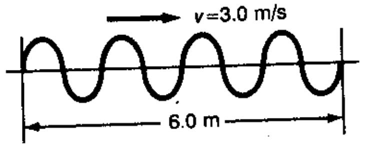
1. The maximum displacement of a particle from its rest position due to wave motion is called (1) amplitude (2) frequency (3) period (4) wavelength
2. A periodic wave that has a frequency of 5.0 hertz and a speed of 10. meters per second has a wavelength of (1) 50. m (2) 2.0 m (3) 0.50 m (4) 0.20 m
3. A point source vibrating up and down on the surface of a container of water produces a periodic surface wave. The wave fronts are (1) straight (2) vertical (3) spherical (4) circular
4. On the wave train shown at the right, which point is in phase with point *A*?
(1) *E* (3) *C*
(2) *B* (4) *D*



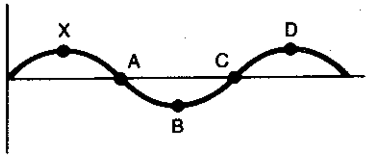
5. A wave has a frequency of 50 hertz. The period of the wave is (1) 0.02 s (2) 0.2 s (3) 2 s (4) 20 s
6. Compared to observations made when both the source and the observer are stationary, when the source of a periodic wave is receding from an observer, there is an apparent increase in the wave's (1) speed (2) frequency (3) wavelength (4) amplitude
7. In the diagram at the right, which two points are in phase? (1) *A* and *E* (2) *A* and *F* (3) *B* and *E* (4) *E* and *F*



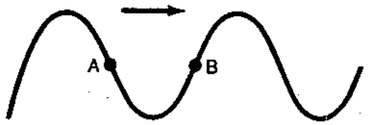
8. What generally occurs when a pulse reaches a boundary between two different media? (1) The entire pulse is reflected. (2) The entire pulse is absorbed. (3) The entire pulse is transmitted. (4) Part of the pulse is transmitted, part reflected, and part absorbed.
9. A periodic wave has a frequency of 10 hertz. The period of the wave is (1) 1 s (2) 0.1 s (3) 0.01 s (4) 0.001 s
10. A train of waves is moving along a string at 3.0 meters per second, as shown at the right. The wavelength is (1) 6.0 m (2) 2.0 m (3) 1.5 m (4) 0.75 m



11. As an ambulance with siren blaring approaches and then passes a stationary observer, the frequency of the sound heard by the observer (1) increases, then decreases (2) decreases, then increases (3) continually increases (4) continually decreases
12. In a transverse wave, the maximum displacement of the medium from its rest position is the wave's (1) amplitude (2) frequency (3) wavelength (4) velocity
13. What is the frequency of a water wave that has a speed of 0.4 meter per second and a wavelength of 0.02 meter? (1) 10 Hz (2) 20 Hz (3) 0.008 Hz (4) 0.05 Hz
14. In the diagram shown at the right, which point is in phase with point *X*?
(1) *A* (3) *C*
(2) *B* (4) *D*

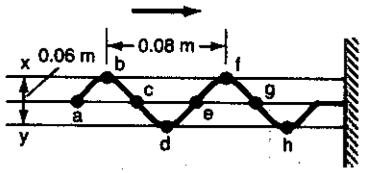


15. If the energy in a longitudinal wave travels from south to north, the particles of the medium move (1) from north to south only (2) both north and south (3) from east to west only (4) both east and west
16. A wave *x* meters long passes through a medium and has a speed of *y* meters per second. The frequency of the wave could be expressed as (1) $\frac{y}{x}$ Hz (2) $\frac{x}{y}$ Hz (3) xy Hz (4) $(x + y)$ Hz
17. If the frequency of a train of waves is 25 hertz, then the period of the wave is (1) 0.040 s (2) 0.25 s (3) 0.40 s (4) 25 s
18. A pulse traveling in a spring transmits (1) energy only (2) mass only (3) both energy and mass (4) neither energy nor mass
19. If the water wave shown is moving toward the right, in which direction are the particles *A* and *B* moving? (1) Both *A* and *B* are moving upward. (2) Both *A* and *B* are moving downward. (3) *A* is moving upward and *B* is moving downward. (4) *A* is moving downward and *B* is moving upward.



20. The frequency of a water wave is 6.0 hertz. If the wave's wavelength is 2.0 meters, then the speed of the wave is (1) 0.33 m/s (2) 2.0 m/s (3) 6.0 m/s (4) 12 m/s
21. As the frequency of a vibrating spring increases, its period of vibration (1) decreases (2) increases (3) remains the same
22. As the amplitude of a wave increases, the energy transported by the wave (1) decreases (2) increases (3) remains the same
23. As a wave travels into a medium in which its speed increases, its wavelength (1) decreases (2) increases (3) remains the same
24. As a pulse travels through a uniform medium, the speed of the pulse (1) decreases (2) increases (3) remains the same

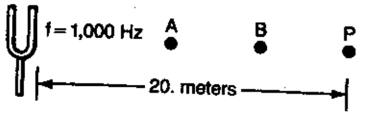
25–29. Base your answers to Questions 25 through 29 on the diagram, which represents a wave traveling to the right along a horizontal material medium. The horizontal distance from *b* to *f* is 0.08 meter. The vertical distance from *x* to *y* is 0.06 meter.



25. If the crest at *b* takes 2.0 seconds to move from *b* to *f*, the speed of the wave is (1) 0.03 m/s (2) 0.04 m/s (3) 0.05 m/s (4) 0.06 m/s
26. If the period of the wave is 2.0 seconds, its frequency is (1) 0.50 Hz (2) 2.0 Hz (3) 5.0 Hz (4) 4.0 Hz
27. The wave's amplitude is (1) 0.03 m (2) 0.04 m (3) 0.05 m (4) 0.06 m
28. As the wave moves to the right from its present position, in which direction will the medium at point *e* first move? (1) down (2) up (3) to the right (4) to the left
29. If the velocity of the wave remains constant, while the frequency is doubled, the wavelength is (1) halved (2) doubled (3) unchanged (4) quartered

30–33. Base your answers to Questions 30 through 33 on the following information.

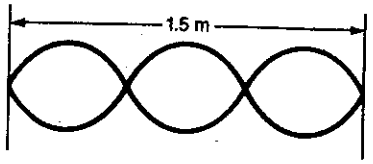
The speed in air of the sound waves produced by the tuning fork in the diagram at the right is 340 meters per second.



30. The time required for the waves to travel from the tuning fork to point *P* is (1) 0.020 s (2) 0.059 s (3) 0.59 s (4) 2.9 s
31. The wavelength of the sound waves produced by the tuning fork is (1) 0.29 m (2) 0.34 m (3) 0.43 m (4) 2.9 m
32. If the waves are in phase at points *A* and *B*, then the minimum distance between points *A* and *B* is (1) 1 wavelength (2) 2 wavelengths (3) ¼ wavelength (4) ½ wavelength
33. If the vibrating tuning fork is accelerated toward point *P*, the pitch observed at point *P* will (1) decrease (2) increase (3) remain the same

1. A student blows air across the top of a soda bottle and produces a note. This is an example of (1) refraction (2) interference (3) diffraction (4) resonance
2. Relative to the radio signals sent by a spacecraft headed away from the earth, the signals that are received on the earth have (1) lower frequency (2) higher frequency (3) lower speed (4) higher speed
3. Total destructive interference of two periodic waves traveling in the same medium can occur if the waves have a phase difference of 180° and have (1) equal amplitudes and different frequencies (2) different amplitudes and equal frequencies (3) equal amplitudes and equal frequencies (4) different amplitudes and different frequencies
4. The particles in a standing wave that do not move appreciably are located at the (1) crests (2) troughs (3) antinodes (4) nodes

5. Standing waves may be produced in the same medium if (1) the wavelength of one wave is half that of the other (2) two waves travel in the same direction (3) two waves travel in opposite directions and then back toward each other (4) the frequency of one wave is three times that of the other
6. What is the wavelength of the standing wave shown at the right?
(1) 1.0 m (3) 3.0 m
(2) 0.5 m (4) 1.5 m



14–17 Base your answers to Questions 14 through 17 on the information below.

An ammeter and a voltmeter are connected properly in a simple circuit to determine the resistance of a lamp in the circuit.

14. How are the meters connected in the circuit with the lamp? (1) Both meters are in parallel. (2) Both meters are in series. (3) The ammeter is in parallel, and the voltmeter is in series. (4) The ammeter is in series, and the voltmeter is in parallel.

15. Compared to the potential drop across the ammeter, the potential drop across the voltmeter is (1) less (2) greater (3) the same

16. Compared to the current through the ammeter, the current through the voltmeter is (1) less (2) greater (3) the same

17. Compared to the internal resistance of the ammeter, the internal resistance of the voltmeter is (1) less (2) greater (3) the same

18. A voltmeter is a galvanometer with (1) a low resistance in series with it (2) a low resistance in parallel with it (3) a high resistance in series with it (4) a high resistance in parallel with it

19. The function of the shunt in an ammeter is to (1) increase the internal resistance of the meter (2) provide a permanent magnetic field (3) permit rotation of the galvanometer coil (4) provide a low-resistance path for the current

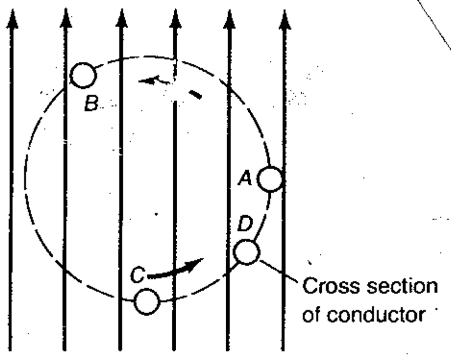
20. A device that converts electrical energy into rotational mechanical energy is a (1) generator (2) laser (3) motor (4) transformer

21. The function of the split-ring commutator in a motor is to (1) reduce the effects of the back EMF (2) provide a permanent magnetic field (3) increase the magnitude of the torque on the coil (4) reverse the direction of the current in the coil each half-rotation

22. An electron is moving perpendicular to the lines of force of a uniform magnetic field. As the speed of the electron increases, the magnetic force on the electron (1) decreases (2) increases (3) remains the same

23. An alternating potential difference is induced in the secondary coil of a transformer if (1) there is no current in the primary coil (2) there is an alternating current in the primary coil (3) there is a constant magnetic flux in the core (4) the magnetic field is constant

24–25. Base your answers to Questions 24 through 25 on the diagram at right, which represents a straight conductor perpendicular to the page, moving in a circular path at constant speed in a uniform magnetic field. Points A, B, C, and D represent different positions of the wire as it moves.



24. The largest potential difference will be induced in the conductor as it moves through position (1) A (2) B (3) C (4) D

25. When the conductor is moving through position B, the direction of the force on the electrons in the conductor will be (1) into the page (2) out of the page (3) toward the top of the page (4) toward the bottom of the page

26. If the strength of the magnetic field is increased, then the maximum potential difference induced in the conductor will (1) decrease (2) increase (3) remain the same

27. If the speed of the conductor is decreased and the magnetic field strength is kept constant, the maximum potential difference induced in the conductor will (1) decrease (2) increase (3) remain the same

28. If the ends of the conductor are connected to a light bulb, the force needed to continue to move the conductor at the same speed will (1) decrease (2) increase (3) remain the same

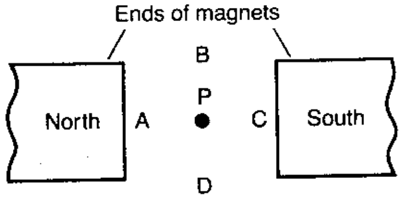
29–30. Base your answers to questions 29 and 30 on the information below.

A transformer with an efficiency of 100% has 100. turns in its primary coil and 300. turns in its secondary coil. The power input to the transformer is 60. watts.

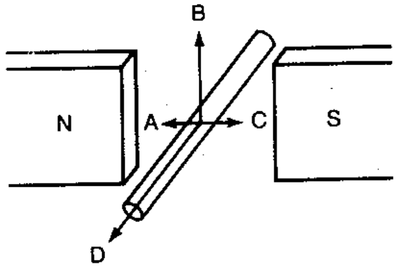
29. The power output of the transformer is (1) 0.0 W (2) 20. W (3) 60. W (4) 180 W

30. The ratio of the potential difference in the primary coil to that in the secondary coil is (1) 1/3 (2) 1/5 (3) 3/1 (4) 6/1

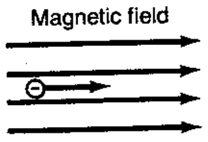
diagram, the direction of
1 magnetic field at point *P* is
ard point
(1) *A* (3) *C*
(2) *B* (4) *D*



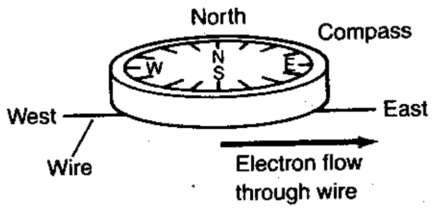
2. An electric potential difference will be induced between the ends of the conductor shown in the diagram when the conductor moves in direction
(1) *A* (3) *C*
(2) *B* (4) *D*



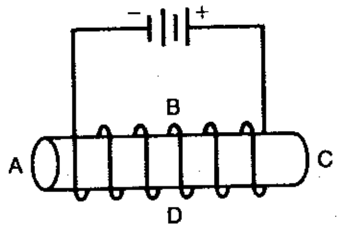
3. An electron moving parallel to a magnetic field as shown in the diagram will experience (1) no magnetic force (2) a magnetic downward force (3) a magnetic force out of the page (4) a magnetic force into the page



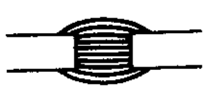
4. If the electrons in the wire shown are flowing eastward, in which direction will the needle of a compass held above the wire point?
(1) north (3) east
(2) south (4) west



5. The north pole of the solenoid shown would be located at point
(1) *A* (3) *C*
(2) *B* (4) *D*



6. Which magnetic-field configuration is not possible?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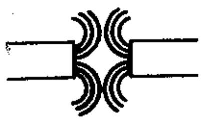
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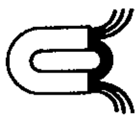
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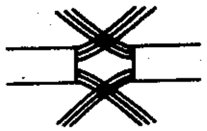
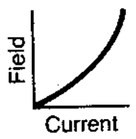

(4)

7. Which graph best represents the relationship between current in a straight conductor and magnetic field strength at a point near the conductor?

(1)


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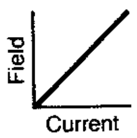

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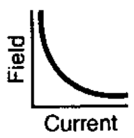

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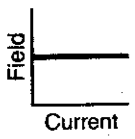
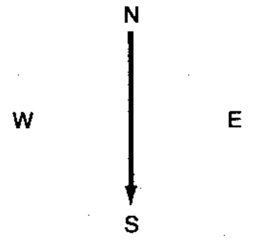
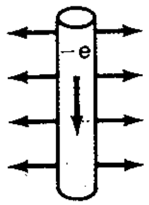


8. A beam of electrons is moving from north to south as shown. The direction of the magnetic field above the beam is toward the
(1) north (3) east
(2) south (4) west



9. An iron core is placed inside a solenoid connected to a voltage source. Which of the following properties of the solenoid will change? (1) magnetic field strength (2) current (3) resistance (4) magnetic polarity

10. Which diagram best represents the magnetic field around a current-carrying conductor? (The x indicates that the field is into the page; the • indicates that the field is out of the page.)

(1)


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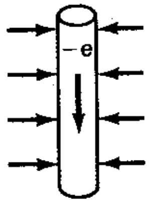
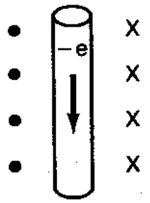


(3)


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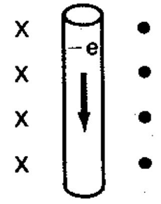

11. As the difference in potential across the terminals of a solenoid increases, its magnetic flux density (1) decreases (2) increases (3) remains the same

12. As the current in a circular loop of wire increases, the magnetic field strength at the center of the loop (1) decreases (2) increases (3) remains the same

13. As the current in a conductor is increased, the strength of the magnetic field at a point near the wire (1) decreases (2) increases (3) remains the same

41. 1
42. 4
43. 4
44. 3
45. 4
46. 4
47. 3
48. 1
49. 3
50. 2
51. 3

College Board Review

Pages 362–363
1. E
2. B
3. B

Page 365
1. D
2. A
3. C

Page 367
1. E
2. D
3. E

Pages 368–369
1. E
2. A
3. D

College Board Practice Test

Pages 369–381
1. E
2. E
3. C
4. D
5. A
6. E
7. C
8. A
9. C
10. C
11. B
12. E
13. C
14. A
15. D
16. D
17. B
18. C
19. E
20. D
21. A
22. C
23. C
24. A
25. B
26. E
27. D
28. C
29. B
30. A
31. D
32. E
33. B
34. C
35. D
36. C
37. B
38. D
39. C
40. D
41. D
42. C
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67. B
68. D
69. E
70. E
71. D
72. D
73. E
74. A
75. D

Regents Examinations

June 1989

Part I
1. 4
2. 2
3. 2
4. 1
5. 4
6. 1
7. 1
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Part II
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118. 1
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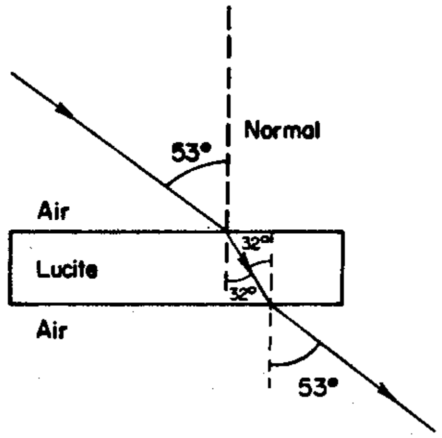
120. 3

Part III

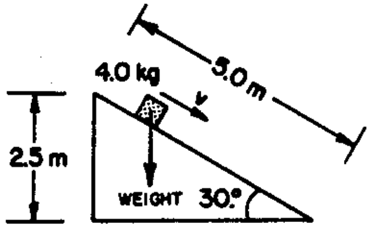
121. (a)

Solution 1	Solution 2
$n_1 \sin\theta_1 = n_2 \sin\theta_2$	$n_2 \sin\theta_2 = n_1 \sin\theta_1$
$1.00(\sin 53°) = 1.50(\sin\theta_2)$	$\sin\theta_2 = \dfrac{n_1 \sin\theta_1}{n_2}$
$1.00(0.7986) = 1.50(\sin\theta_2)$	$\sin\theta_2 = \dfrac{1.00 \times 0.7986}{1.50}$
$0.5324 = \sin\theta_2$	$\sin\theta_2 = 0.5324$
$32° = \theta_2$	$\theta_2 = 32°$

(b)



122. (a)



(b) $\Delta PE = mg\Delta h = (4.0\text{ kg})(9.8\text{ m/s}^2)(\times 2.5\text{ m}) = 98\text{ J}$

(c) **Solution 1**

$PE_{top} = KE_{bottom} = \frac{1}{2}mv^2$

$98\text{ J} = \frac{1}{2}(4.0\text{ kg})v^2$

$98\text{ J} = (2.0\text{ kg})v^2$

$49\text{ J/kg} = v^2$

$v = 7.0\text{ m/s}$

Solution 2

$v_f^2 = v_i^2 + 2a\Delta s$

$v_f^2 = 0 + 2(4.9\text{ m/s}^2)(5.0\text{ m})$

$v_f^2 = 49\text{ m}^2/\text{s}^2$

$v_f = 7.0\text{ m/s}$

June 1990

Part I

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Part II

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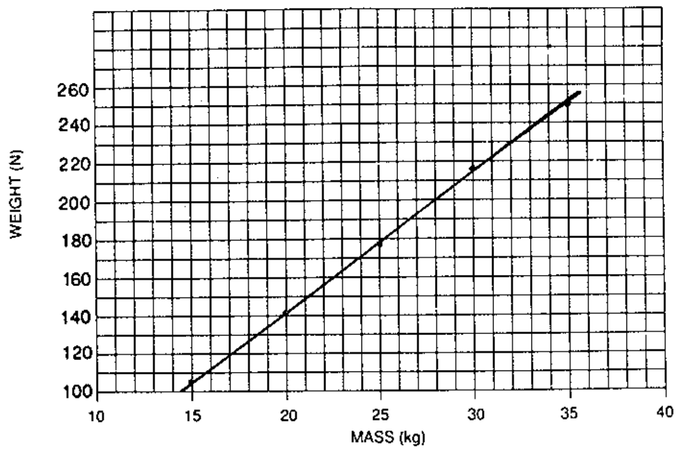
Part III

121. (a)



(b) **Solution 1**

$W = mg$

$g = \frac{W}{m}$

$= \frac{170\text{ N}}{24\text{kg}}$

$= 7.08\text{ N/kg or }7.08\text{ m/s}^2$

Solution 2

$g = \frac{\Delta y}{\Delta x}$

$= \frac{220\text{N} - 120\text{ N}}{31\text{ kg} - 17\text{ kg}}$

$= \frac{100}{14}$

$= 7.1\text{ N/kg or }7.1\text{ m/s}^2$

122. (a) 60.Ω

(b) **Solution 1**

$V = IR$

$I = \frac{V}{R}$

$I = \frac{120\ \text{V}}{60.\ \Omega}$

$I = 2.0\ \text{A}$

Solution 2

$V = IR$

$120\ V = I(60\ \Omega)$

$\frac{120}{60} = I$

$2\ \text{A} = I$

(c) 4.0 A

(d) 120 V

June, 1991

Part I

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Part II

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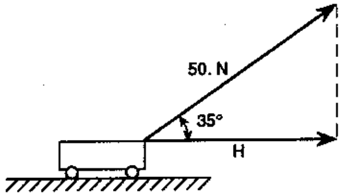
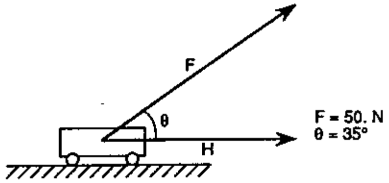
Part III

121. a–b





c. 41 N

122. a.

$$v = \lambda f$$
$$\lambda = \frac{v}{f}$$
$$= \frac{1.5 \times 10^3\ \text{m/s}}{5.0 \times 10^3\ \text{Hz}}$$
$$= 0.30\ \text{m}$$

or

$$v = \lambda f$$
$$1.5 \times 10^3\ \text{m/s} = \lambda(5.0 \times 10^3\ \text{Hz})$$
$$\frac{1.5 \times 10^3}{5.0 \times 10^3} = \lambda$$
$$3.0 \times 10^{-1}\ \text{m} = \lambda$$

b.

$$\bar{v} = \frac{\Delta s}{\Delta t}$$

$$1.5 \times 10^3\ \text{m/s} = \frac{\Delta s}{2\text{s}}$$
$$\Delta s = 3 \times 10^3\ \text{m}$$

or

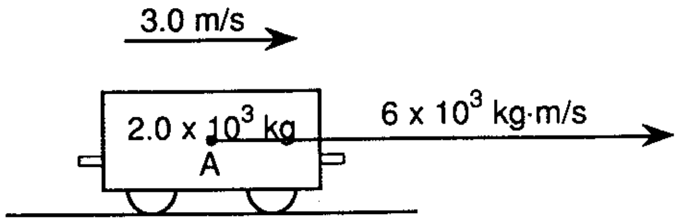
$$\Delta s = \bar{v}\Delta t$$
$$= 1.5 \times 10^3\ \text{m/s}\ (4.0\ \text{s})$$
$$= 6.0 \times 10^3\ \text{m [whole trip]}$$
$$\Delta s = 3.0 \times 10^3\ \text{m [one way]}$$

117. a. $p = mv$
$= 2.0 \times 10^3\text{kg}\,(3.0\text{m/s})$
$= 6.0 \times 10^3\text{kg}\bullet\text{m/s}$

or $m = 2.0 \times 10^3\text{kg}$
$v = 3.0\text{ m/s}$

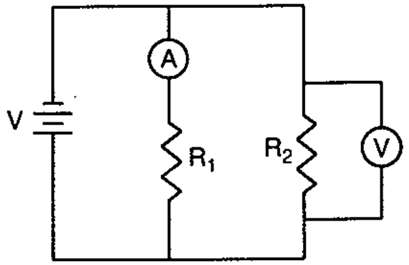
$p = mv$
$= 2.0 \times 10^3(3.0)$
$= 6000\text{ kg}\bullet\text{m/s}$

b.



c. The two cars have zero momentum because the initial momentum of the system is zero, so the final momentum of the system must be zero. Momentum must be conserved.

118. a.

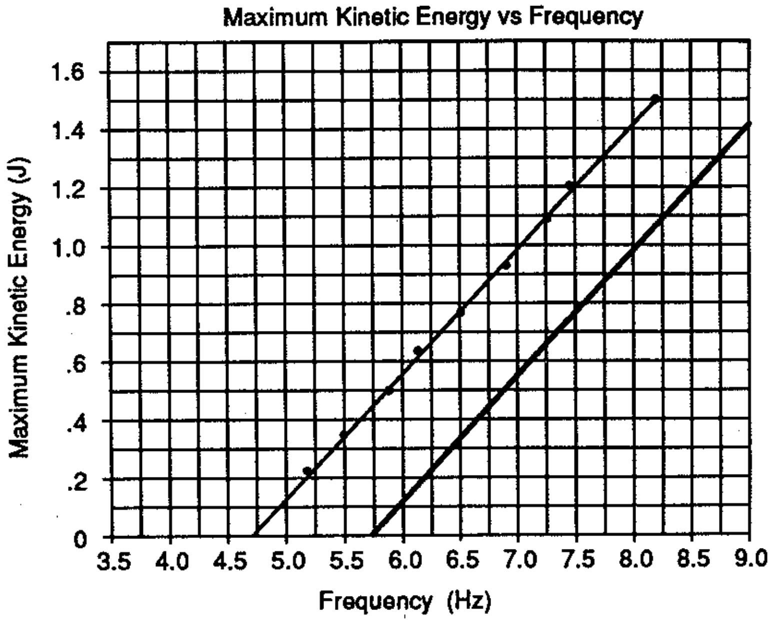


b. $V = IR$
$12\text{V} = I(18\Omega)$
$0.67\text{A} = I$

or $V = 12\text{V}$
$R = 18\Omega$

$$I = \frac{V}{R} = \frac{12}{18} = 0.67\text{A}$$

123.



June, 1992

Part I

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Part II

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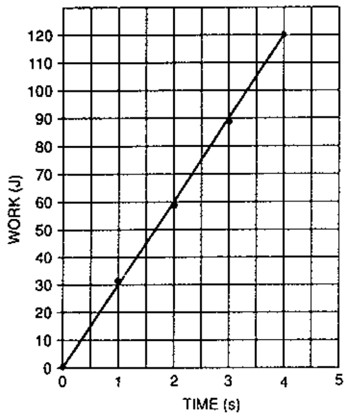
Part III

116. a.



b. slope $= \frac{\Delta W}{\Delta t}$ *or* $\frac{\Delta y}{\Delta x} = \frac{120J}{4s}$ (since graph passes through origin)

$= \frac{120J - 60J}{4s - 2s}$ $= 30J/s$

$= 30\ J/s$

or $P = \frac{W}{\Delta t}$

$= \frac{120J}{4s}$

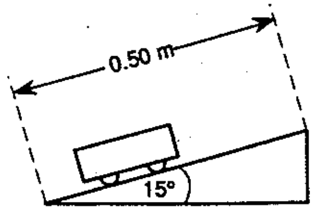
$= 30W$

c. 2.5s ±0.3s

52. As the time required to do a given quantity of work decreases, the power developed
(1) decreases
(2) increases
(3) remains the same

53. As the speed of a bicycle moving along a level horizontal surface changes from 2 meters per second to 4 meters per second, the magnitude of the bicycle's gravitational potential energy
(1) decreases
(2) increases
(3) remains the same

54. As shown in the diagram below, pulling a 9.8-newton cart a distance of 0.50 meter along a plane inclined at 15° requires 1.3 joules of work.



If the cart were raised 0.50 meter vertically instead of being pulled along the inclined plane, the amount of work done would be
(1) less
(2) greater
(3) the same

Group 1—Motion in a Plane

If you choose this group, be sure to answer questions 56–65.

Base your answers to questions 56 through 58 on the information below.

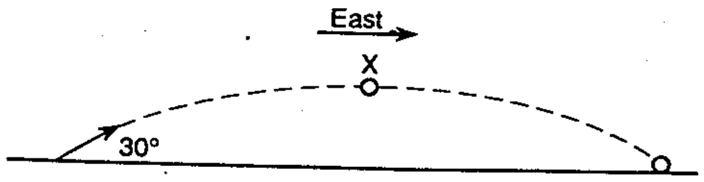
An object is thrown horizontally off a cliff with an initial velocity of 5.0 meters per second. The object strikes the ground 3.0 seconds later.

56. What is the vertical speed of the object as it reaches the ground? [Neglect friction.]
(1) 130 m/s
(2) 29 m/s
(3) 15 m/s
(4) 5.0 m/s

57. How far from the base of the cliff will the object strike the ground? [Neglect friction.]
(1) 2.9 m
(2) 9.8 m
(3) 15 m
(4) 44 m

58. What is the horizontal speed of the object 1.0 second after it is released? [Neglect friction.]
(1) 5.0 m/s
(2) 10. m/s
(3) 15 m/s
(4) 30. m/s

Base your answers to questions 59 and 60 on the diagram below which shows a ball thrown toward the east and upward at an angle of 30° to the horizontal. Point X represents the ball's highest point.

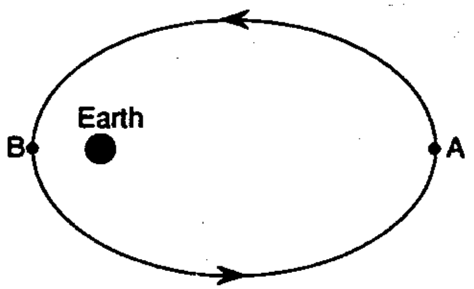


59. What is the direction of the ball's velocity at point X? [Neglect friction.]
(1) down
(2) up
(3) west
(4) east

60. What is the direction of the ball's acceleration at point X? [Neglect friction.]
(1) down
(2) up
(3) west
(4) east

61. A batted softball leaves the bat with an initial velocity of 44 meters per second at an angle of 37° above the horizontal. What is the magnitude of the initial vertical component of the softball's velocity?
(1) 0 m/s
(2) 26 m/s
(3) 35 m/s
(4) 44 m/s

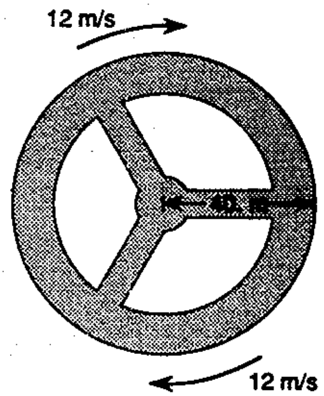
62. The diagram shows the path of a satellite in an elliptical orbit around the Earth.



As the satellite moves from point A to point B, what changes occur in its potential and kinetic energies?
(1) Both potential energy and kinetic energy increase.
(2) Both potential energy and kinetic energy decrease.
(3) Potential energy increases and kinetic energy decreases.
(4) Potential energy decreases and kinetic energy increases.

63. A satellite is in geosynchronous orbit around the Earth. The period of the satellite's orbit is closest to
(1) 6 hours
(2) 12 hours
(3) 24 hours
(4) 48 hours

Base your answers to questions 64 and 65 on the diagram below which represents a space station shaped like a wheel and having a radius of 40. meters. The station is rotating clockwise with a speed of 12 meters per second at its outer wall. A 50-kilogram astronaut is standing inside the space station against the outer wall.



64. What is the apparent weight of the astronaut? [Consider only the interacting forces between the space station and the astronaut.]
(1) 3.6 N
(2) 15 N
(3) 180 N
(4) 490 N

Note that question 65 has only three choices.

65. If the speed of rotation of the space station were doubled, the centripetal acceleration of the astronaut would
(1) decrease
(2) increase
(3) remain the same

A student performs a laboratory activity in which a 15-newton force acts on a 2.0-kilogram mass. The work done over time is summarized in the table below.

DATA TABLE

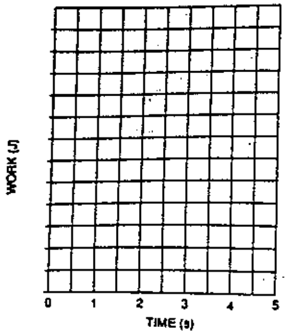
Time (s)	Work (J)
0	0
1.0	32
2.0	59
3.0	89
4.0	120

a Using the information in the data table, construct a graph on a grid like the one below, following the directions below.

(1) Develop an appropriate scale for work, and plot the points for a *work-versus-time* graph. [1]
(2) Draw the best-fit line. [1]

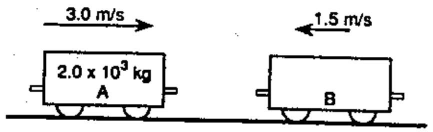
b Calculate the value of the slope of the graph constructed in part *a*. (Show all calculations, including equations and substitutions with units.) [2]

c Based on your graph, how much time did it take to do 75 joules of work? [1]



117. Base your answers to parts *a* through *c* on the diagram and information below.

Two railroad carts, A and B, are on a frictionless, level track. Cart A has a mass of 2.0×10^3 kilograms and a velocity of 3.0 meters per second toward the right. Cart B has a velocity of 1.5 meters per second toward the left. The magnitude of the momentum of cart B is 6.0×10^3 kilogram-meters per second. When the two carts collide, they lock together.



a What is the magnitude of the momentum of cart A before the collision? (Show all calculations, including equations and substitutions with units.) [2]

b On the diagram on your answer sheet, construct a scaled vector that represents the momentum of cart A before the collision. The momentum vector *must* be drawn to a scale of 1.0 centimeter = 1,000 kilogram-meters per second. *Be sure your final answer has correct labels (numbers and units).* [1]

c In one or more *complete sentences*, describe the momentum of the two carts after the collision and justify your answer based on the initial momenta of both carts. [2]

PHYSICS

June 17, 1992

PART I

Answer all 55 questions in this part. [65]

Directions (1–55): For *each* statement or question, select the word or expression that, of those given, best completes the statement or answers the question.

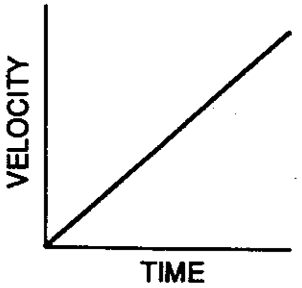
1. The velocity of a car changes from 60. meters per second north to 45 meters per second north in 5.0 seconds. The magnitude of the car's acceleration is
(1) 9.8 m/s^2
(2) 15 m/s^2
(3) 3.0 m/s^2
(4) 53 m/s^2

2. The height of a doorknob above the floor is approximately
(1) 1×10^2 m
(2) 1×10^1 m
(3) 1×10^0 m
(4) 1×10^{-2} m

3. Which two terms represent a vector quantity and the scalar quantity of the vector's magnitude, respectively?
(1) acceleration and velocity
(2) weight and force
(3) speed and time
(4) displacement and distance

4. A group of bike riders took a 4.0-hour trip. During the first 3.0 hours, they traveled a total of 50. kilometers, but during the last hour they traveled only 10. kilometers. What was the group's average speed for the entire trip?
(1) 15 km/hr
(2) 30. km/hr
(3) 40. km/hr
(4) 60. km/hr

5. The graph below represents the motion of a body moving along a straight line.



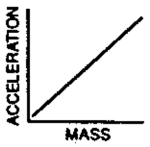
According to the graph, which quantity related to the motion of the body is constant?
(1) speed
(2) velocity
(3) acceleration
(4) displacement

6. A student walks 1.0 kilometer due east and 1.0 kilometer due south. Then she runs 2.0 kilometers due west. The magnitude of the student's resultant displacement is closest to
(1) 0 km
(2) 1.4 km
(3) 3.4 km
(4) 4.0 km

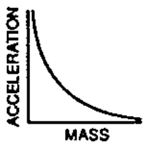
7. A locomotive starts from rest and accelerates at 0.12 meter per second^2 to a speed of 2.4 meters per second in 20. seconds. This motion could best be described as
(1) constant acceleration and constant velocity
(2) increasing acceleration and constant velocity
(3) constant acceleration and increasing velocity
(4) increasing acceleration and increasing velocity

8. A clam dropped by a sea gull takes 3.0 seconds to hit the ground. What is the sea gull's approximate height above the ground at the time the clam was dropped?
(1) 15 m
(2) 30. m
(3) 45 m
(4) 90. m

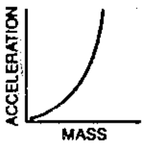
9. Which graph best represents the relationship between mass and acceleration due to gravity for objects near the surface of the earth? [Neglect air resistance.]



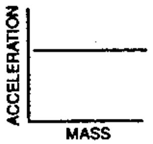
(1)



(2)



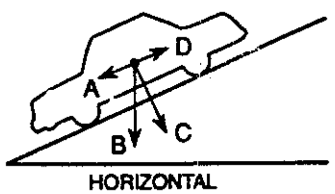
(3)



(4)

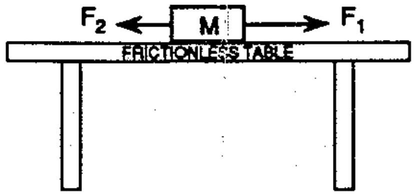
10. Two concurrent forces have a maximum resultant of 45 newtons and a minimum resultant of 5.0 newtons. What is the magnitude of each of these forces?
(1) 0.0 N and 45 N
(2) 5.0 N and 9.0 N
(3) 20. N and 25 N
(4) 0.0 N and 50. N

11. The diagram below represents a car resting on a hill.



Which vector best represents the weight of the car?
(1) *A*
(2) *B*
(3) *C*
(4) *D*

12. In the diagram below, box *M* is on a frictionless table with forces F_1 and F_2 acting as shown.



If the magnitude of F_1 is greater than the magnitude of F_2, then the box is
(1) moving with a constant speed in the direction of F_1
(2) moving with a constant speed in the direction of F_2
(3) accelerating in the direction of F_1
(4) accelerating in the direction of F_2

13. A 1.2×10^3-kilogram automobile in motion strikes a 1.0×10^{-4}-kilogram insect. As a result, the insect is accelerated at a rate of 1.0×10^2 meters per second^2. What is the magnitude of the force the insect exerts on the car?
(1) 1.0×10^{-2} N
(2) 1.2×10^{-2} N
(3) 1.0×10^1 N
(4) 1.2×10^3 N

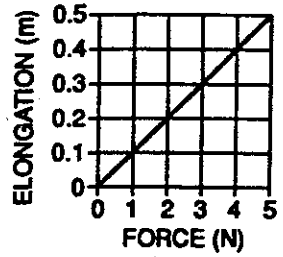
14. When a satellite is a distance *d* from the center of the Earth, the force due to gravity on the satellite is *F*. What would be the force due to gravity on the satellite when its distance from the center of the Earth is 3*d*?
(1) F
(2) $\frac{F}{9}$
(3) $\frac{F}{3}$
(4) $9F$

15. Two rocks weighing 5 newtons and 10 newtons, respectively, fall freely from rest near the Earth's surface. After 3 seconds of free-fall, compared to the 5-newton rock, the 10-newton rock has greater
(1) acceleration
(2) height
(3) momentum
(4) speed

16. A force of 20. newtons is exerted on a cart for 10. seconds. How long must a 50.-newton force act to produce the same impulse?
(1) 10. s
(2) 2.0 s
(3) 5.0 s
(4) 4.0 s

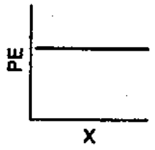
17. A 20.-kilogram object strikes the ground with 1,960 joules of kinetic energy after falling freely from rest. How far above the ground was the object when it was released?
(1) 10. m
(2) 14 m
(3) 98 m
(4) 200 m

18. The graph below shows the elongation of a spring as a function of the force.

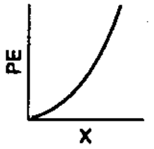


What is the value of the spring constant?
(1) 0.1 m/N
(2) 0.1 N/m
(3) 10 m/N
(4) 10 N/m

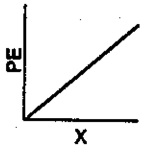
19. Which graph below best represents the relationship between the potential energy stored in a spring (PE) and the change in the length of the spring from its equilibrium position (*X*)?



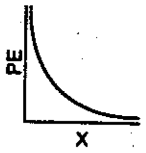
(1)



(2)

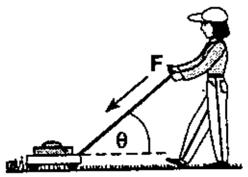


(3)



(4)

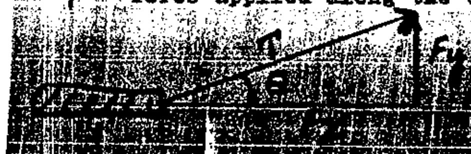
51. A lawnmower is pushed with a constant force *F*, as shown in the diagram below.



As angle θ between the lawnmower handle and the horizontal increases, the horizontal component of *F*
(1) decreases
(2) increases
(3) remains the same

Efficiency "Catch-up" material for Physics 1 Classes of Sec.'s 11 & 06
Types of vector problems from the second half of Chapter 4 that you must be able to solve. All of them require the finding of componets (specified, often at right angles to each other) which, when combined produce the given vector. The principal types are:

1 The sled, or cart being pulled with a slanting rope. You are asked to find the horizontal component and the vertical component of the slant force applied along the cord.



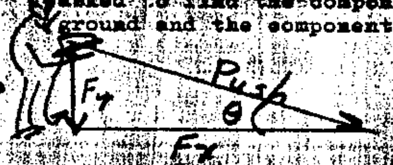
$\frac{F_y}{T} = \sin\theta$ $F_y = T\sin\theta$

$\frac{F_x}{T} = \cos\theta$ $F_x = T\cos\theta$

$F_y/F_x = \tan\theta$

[illegible] problem where we are given an old lawn mower where the push [illegible] known and the angle of slant is known and we are asked to find the component which moves the mower horizontally along the ground and the component which tends to push the mower into the ground.

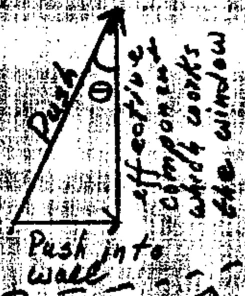
2



$F_y = \text{Push } \sin\theta$
$F_x = \text{Push } \cos\theta$

Now you may remember, (in the old building) that we had something called the window pole which was used to raise and lower the windows. It was applied as nearly parallel to the wall as possible to maximize the effective component which raised or lowered the window.

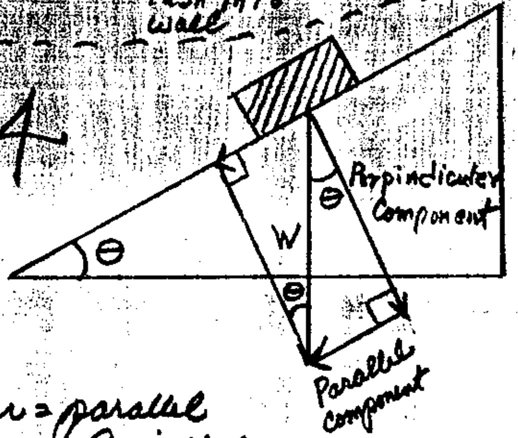
3



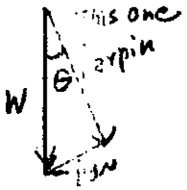
$\frac{\text{Vertical Comp}}{\text{Push}} = \cos\theta$ $VC = \text{Push } \cos\theta$

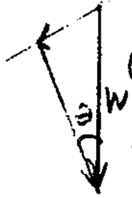
$\frac{\text{Horizontal Comp}}{\text{Push}} = \sin\theta$ $HC = \text{Push } \sin\theta$

4



Here we have an object on an inclined plane which makes an angle θ with the horizontal. We are asked to find the component of the weight (which is straight down) which is acting parallel to the inclined plane. We are also asked to find the component of the weight which is perpindicular to the inclined plane and which holds the object against the plane as it slides down hill. Since all the θ s are equal we may use either of the triangles shown.





Par = W sin θ
Perpin = W cos θ
or This one

Par = parallel
Perpin = Perpindicular

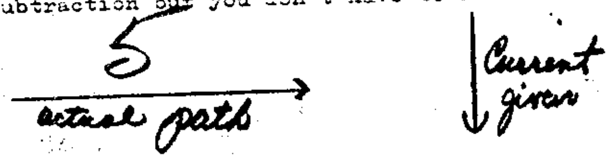
2nd half of ch. 4

More problems of the type found in the second half of Ch. 4

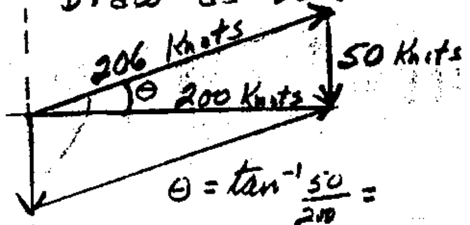
Here is a type of problem where a boat (or plane) is moving in water (or air)
The desired course is given and if the current (or wind) is given we are asked to find the heading of the craft which will give the desired course.

A variant of this problem is when the desired course and heading are given and we are asked to find the current (or wind). It really involves vector subtraction but you don't have to know this to solve the problem.

5



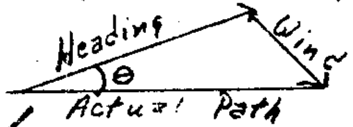
Draw as below



$\theta = \tan^{-1}\frac{50}{200} =$

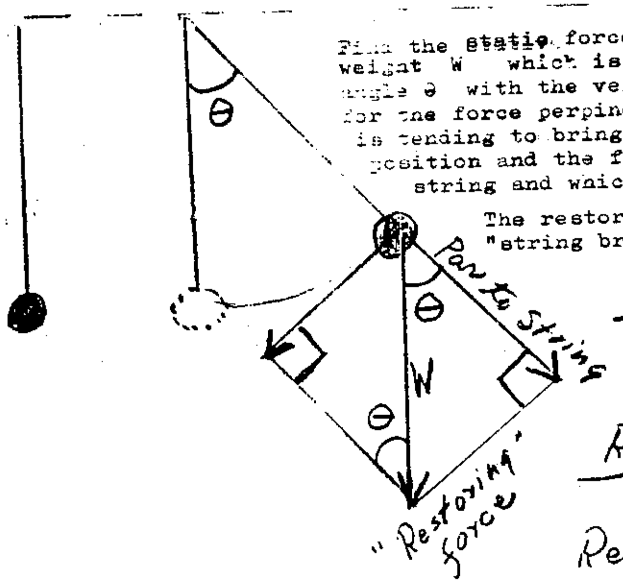
$\theta = 14°$

Another example



6 If you can find θ and are given Heading and Actual path you can find the mag. of the wind by using the law of sines. The angle of the wind can be found by using the law of cosines.

7



Find the static forces on a pendulum bob of weight W which is pulled to one side at an angle θ with the vertical. Here are solving for the force perpindicular to the string which is tending to bring the bob back to the central position and the force which is parallel to the string and which tends to break the string.

The restoring Force is W sin θ and the "string breaking" force is W cos θ.

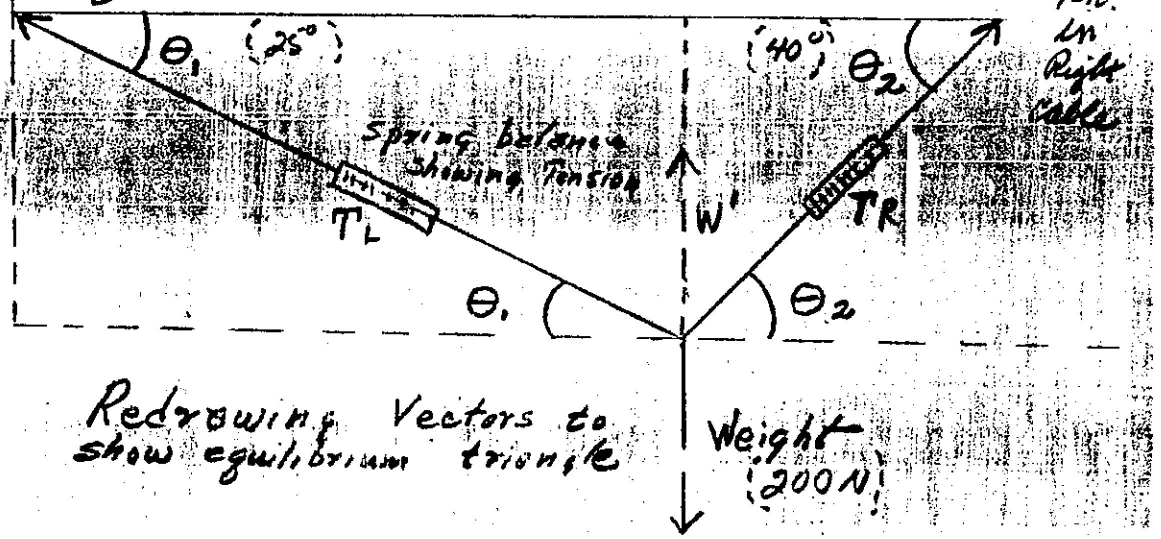
$\frac{\text{Par}}{W} = \cos\theta$ $\text{Par} = W\cos\theta$

$\frac{\text{Restoring F}}{W} = \sin\theta$

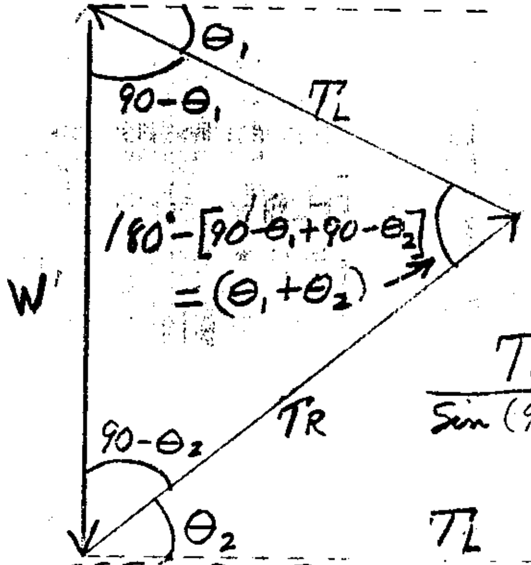
$\text{Restoring F} = W\sin\theta$

8 Deriving 2 formulas for tension in Cables supporting a weight

T_L = tension in left cable, T_R = ten. in Right cable



Redrawing Vectors to show equilibrium triangle



$$\frac{T_R}{\sin(90°-\theta_1)} = \frac{W}{\sin(\theta_1+\theta_2)}$$

$$\text{or } T_R = \frac{W\cos\theta_1}{\sin(\theta_1+\theta_2)}$$

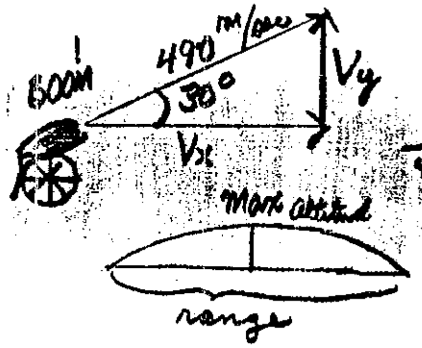
$$\frac{T_L}{\sin(90°-\theta_2)} = \frac{W}{\sin(\theta_1+\theta_2)}$$

$$\text{or } T_L = \frac{W\cos\theta_2}{\sin(\theta_1+\theta_2)}$$

Try Numbers:
$W = 200N$ $\theta_1 = 25°$
$\theta_2 = 40°$

$T_R = 200N$
$T_L = 169N$ ← Numerical example

Here is a problem with slanting velocities which seems a little like the one with a sled. But it's reall quite different in the physical world. We are given a cannon firing a shell at an angle of 30° with a muzzle velocity of 480 meter's/sec. We are required to find the vertical and horizontal components of the muzzle velocity. As can be seen from the diagram $V_y = 480 \sin 30°$ and $V_x = 480 \cos 30°$



$$\frac{V_y}{480} = \sin 30° \quad V_y = (490)(.5) = 245\frac{m}{sec}$$

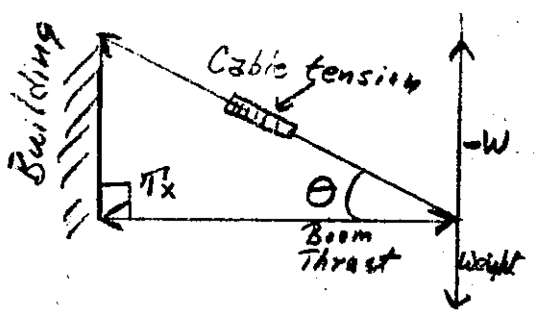
$$\frac{V_x}{480} = \cos 30° \quad V_x = (480)(.866) = 415.7\frac{m}{sec}$$

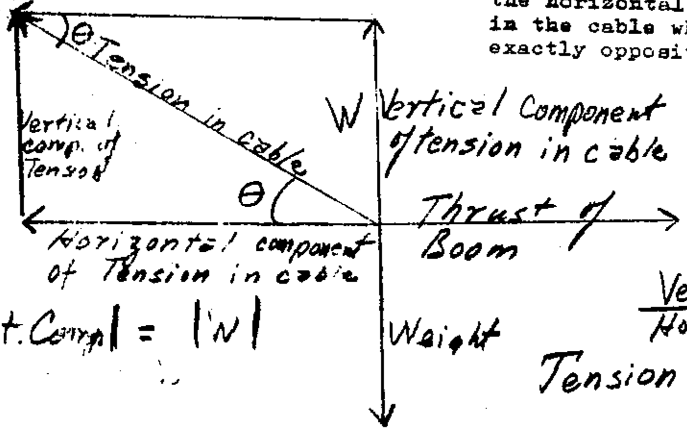
From the value of the initial vertical component of velocity we are able to find the time to reach the maximum altitude. It is $\frac{249}{9.8} = 25$ sec.

Since it took 25 seconds to go up it will take 25 seconds to come down and it was in the air for 50 seconds. All the while it was in the air it was moving forward with a constant horizontal velocity of 415.7 m/sec. The range, or total horizontal displacement is (415.7 m/sec) x (50 sec) = 20,785 meters. The maximum height of the shell was 25 sec x the **average** vertical velocity or (25) x $\frac{(245 + 0)}{2}$ = 3062.5 meters.

THIS IS CALLED THE PROJECTILE PROBLEM. IT'S SOLUTION INVOLVES THE CONCEPT THAT THE HORIZONTAL AND VERTICAL COMPONENTS ACT IN DEPENDENTLY OF EACH OTHER AND DO NOT AFFECT EACH OTHER.

The next problem is called the "boom" and cable problem. It features a horizontal rigid pole called a "boom" the far end of said pole being supported by a flexible cable pulled taut with tension and attached to the wall of a building. The angle which the cable makes with the wall of the building is usually given and a weight is usually hung from the end of the boom where the supporting cable is attached. If the weight is also given we can find (a) the tension in the cable and (b) the so called "thrust" of the boom which is really how hard the boom must push against the horizontal component of the tension in the cable which is toward the wall and exactly opposite to the thrust of the boom.




θ Tension in cable
Vertical comp. of Tension
W
Vertical Component of tension in cable
θ
Horizontal component of Tension in cable
Thrust of Boom
Weight

$$|\text{Vert. Comp}| = |W|$$

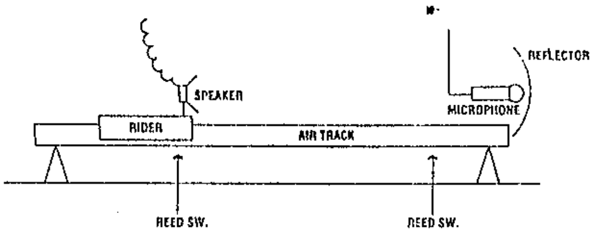
$$\frac{\text{Vert. Comp}}{\text{Tension}} = \sin\theta$$

$$\frac{\text{Horizontal Comp.}}{\text{Tension}} = \cos\theta$$

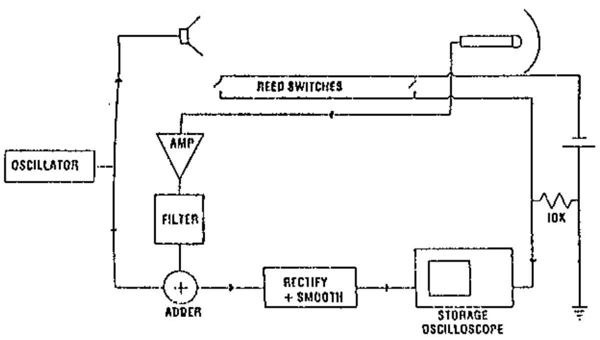
$$\frac{\text{Vert. Comp}}{\text{Horiz. Comp}} = \tan\theta$$

$$\text{Tension} = \frac{\text{Weight}}{\sin\theta}$$

EXPERIMENT ON THE DOPPLER EFFECT



(a) APPARATUS



Students will almost certainly be familiar with the Doppler effect in everyday life. The pitch of a police car siren rises as it approaches and falls after it passes on the street; the pitch of train, truck, or car engine sounds similarly changes as they speed past the observer. In general, the frequency of the sound heard from an approaching source is raised above that of a stationary source, and that from a receding source is lowered. The effect holds for any form of traveling wave, not only sound. The Doppler effect in light, for example, is extremely important in astronomical observations, providing evidence for the expansion of the universe. It is also used in modern technology for measuring flow velocity: for example, of blood in an artery.

In this experiment, using sound, students examine the relationship between the observed frequency shift and the velocity of the source. They will discover the simple result that, when the source velocity is small compared to the velocity of sound, the shift Δ is proportional to the source velocity. As a bonus they can also measure the velocity of sound.

Two other cases of the Doppler effect are demonstrated: when the source is stationary and the observer is moving, and when the source and the observer are both at rest but the sound is reflected from a moving object—the effect used in a radar speed trap to measure the speed of cars, either from the roadside or from another car.

Observation of the police-car Doppler effect tells us that at speeds of about 40 mph, the frequency shift is only a few percent. We need an experiment in which, on a laboratory bench, both the velocity and the frequency shift can be measured simultaneously. In this experiment, the velocity is kept small, so it can easily be measured by timing between fixed points. The very small frequency shift is measured by using the phenomenon of 'beats': when two sounds of frequency f_1 and f_2 are heard simultaneously, where f_1 is higher, the resultant sound intensity oscillates at the beat frequency $f_{beat} = f_1 - f_2 = \Delta f$. Timing the beats gives an accurate method of determining the frequency difference Δf.

Uniform velocity is achieved using an air track, giving almost frictionless motion. A small speaker is fixed to a rider on the air track. A small magnet on the rider activates reed switches at two different positions along the track, indicating the time at which the rider passed each marker point. Timing is determined from the calibrated time base on an oscilloscope.

The drag of the speaker leads is kept negligibly small by using very slender coiled wires and holding these above the speaker as it moves during a measurement.

The stationary observer is a microphone at the end of the track. The signal received is subject to the inverse square law of distance, and so would normally vary in strength as the rider approaches the microphone. However, a roughly constant output level is achieved, first by using a parabolic reflector to collect the sound and focus it onto the microphone (this has the additional effect of reducing the sensitivity to background noise in the laboratory), and second by using an automatic gain control amplifier on the microphone output.

The background noise is rather loud because of the compressor used to pressurize the air track. Its effect is dramatically reduced by passing the sound from the microphone through an electronic filter that passes only a narrow frequency band at the source frequency. Since it is a precise frequency, the source signal is passed unhindered. The background noise, however, contains a wide range of different frequencies, and only a very small proportion of these passes through the filter. Thus, the noise level is greatly reduced while the signal is not affected.

Following the amplifier and filter, the sinusoidal signal from the microphone is added to the signal driving the source, and the beat frequency of the two signals can be clearly heard in headphones. This sound has been put onto the soundtrack for program users to hear. To measure the beat frequency, the beat waveform is first rectified and then smoothed, so that the final signal is simply proportional to the intensity of the beat. This is then displayed on the oscilloscope simultaneously with the signals from the reed switches. Thus, in one oscilloscope scan, the screen displays both the beats and the pulses from the velocity-measuring sensors, which makes it possible to measure both frequency shift and velocity. The oscilloscope is a storage type, which contains enough memory to hold and continuously display a single scan.

Theory indicates that the frequency shift Δf should be given by

$$\Delta f = \frac{f}{c} v$$

where c is the velocity of sound, v that of the source and f the frequency of the sound used. A graph of Δf against v should be a straight line through the origin. In the first experiment, does the origin represent a valid experimental point? From the gradient, students should be able to obtain a good value for c and perhaps assess its accuracy. It should be as good as ±1%.

The value obtained for the velocity of sound is likely to be higher than the accepted value of 332 ms^{-1}. First, the value quoted is for air at STP (standard temperature and pressure). Theory shows that

$$c = \left(\frac{\gamma k T}{M}\right)^{1/2}$$

where T is the absolute temperature, M is the molecular mass of the gas, γ is a constant of magnitude 1.40, and k is Boltzmann's constant ($1.38 \times 10^{-23}\,\mathrm{JK}^{-1}$). This will enable students to correct their measured value for c for the influence of room temperature.

If the value still differs by more than the estimated margin of error from the accepted value, students should try to think of possible reasons. What, for example, will be the effect of water vapor in the air?

In the second experiment shown in the program, the source is stationary and the observer is moving. A radiomicrophone is used here to avoid trailing wires. The Doppler effect is observed in a manner very similar to the previous case. Theory shows that for $v \ll c$ the two cases are the same. (However, for velocities comparable with the velocity of sound, the two cases are in principle different.) The experiment serves simply as a demonstration, and no measurements are taken.

In the final experiment, sound is reflected from a moving object, here a plane reflector mounted on the rider. There is a significant difference in this case: for a given velocity, the beat frequency is twice that for a moving source. This is easier to understand when one thinks of the reflector as producing a moving image of the source, which is then seen by a stationary detector.

Student Activities

Students should be ready to observe the distance between the markers on the trackside, and then to construct a table of the following readings: frequency of sound used; time between markers; number of beats n; time for n beats. Other columns will be needed for inserting the calculated values of the velocity v and the beat frequency Δf. The room temperature, which is important, should also be noted.

In the program, measurements are made at four different velocities. A second set of measurements is then taken at a different frequency. These are not shown in the program but are given in the table below. Students should plot Δf against v on the same graph as for the first frequency.

f = 3,494 kH$_z$. Distance between markers = 1.80 m

Time between markers	No of beats	Time for n beats
12.2 sec	20	13.6 sec
7.6 sec	20	8.5 sec
3.9 sec	20	4.4 sec
3.1 sec	20	3.5 sec